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EROSION CONTROL OF SCOUR DURING CONSTRUCTION REPORT 6

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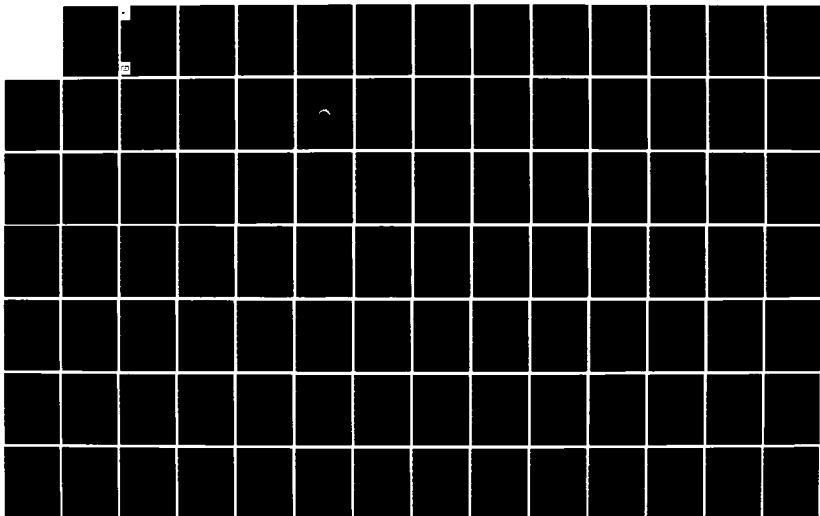
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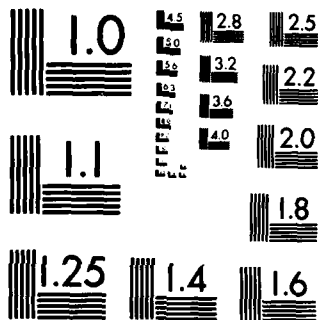
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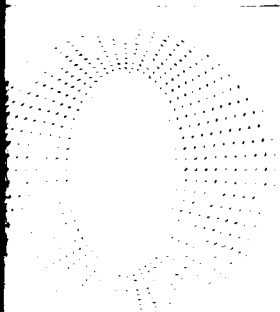
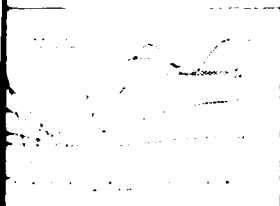
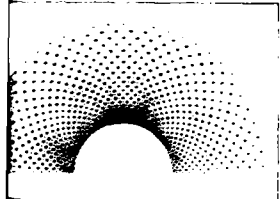


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HYDRAULICS  
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TECHNICAL REPORT HL-80-3

# EROSION CONTROL OF SCOUR DURING CONSTRUCTION

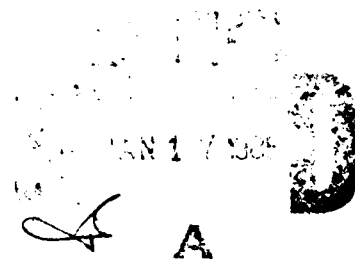
Report 6  
FINITE — A NUMERICAL MODEL  
FOR COMBINED REFRACTION  
AND DIFFRACTION OF WAVES

by

James R. Houston, Lucia W. Chou

Hydraulics Laboratory

DEPARTMENT OF THE ARMY  
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September 1984  
Report 6 of a Series

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20. ABSTRACT (Continued).

variations (at much lower cost than required by three-dimensional models that are appropriate for problems involving rapid depth variations). The model does not provide a mechanism for energy dissipation, and thus energy loss through wave breaking is simulated by permitting waves to propagate out of the computational region. The program documentation, user guide, and sample problem output, are provided.

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## PREFACE

The study reported herein was authorized as a part of the Civil Works Research and Development Program by the Office, Chief of Engineers (OCE), US Army. This particular work unit, Erosion Control of Scour During Construction, is part of the Improvement of Operations and Maintenance Techniques (IOMT) Program. Mr. James L. Gottesman was the OCE Technical Monitor for the IOMT Program during preparation and publication of this report.

This study was conducted during the period 1 January 1981 through 31 March 1982 by personnel of the Hydraulics Laboratory of the US Army Engineer Waterways Experiment Station (WES) under the general supervision of Messrs. H. B. Simmons, Chief of the Hydraulics Laboratory; F. A. Herrmann, Jr., Assistant Chief of the Hydraulics Laboratory; R. A. Sager, Chief of the Estuaries Division and IOMT Program Manager; Dr. R. W. Whalin and Mr. C. E. Chatham, former and acting Chiefs of the Wave Dynamics Division, respectively; Mr. D. D. Davidson, Chief of the Wave Research Branch; and Dr. J. R. Houston, Research Hydraulic Engineer and Principal Investigator for the Erosion Control of Scour During Construction work unit. The Wave Dynamics Division was transferred to the Coastal Engineering Research Center (CERC) of the WES on 1 July 1983 under the direction of Dr. Whalin, Chief of the Coastal Engineering Research Center. Computer programming for this study was performed by Ms. L. Chou, Mathematician. This report was prepared by Dr. Houston and Ms. Chou.

Commanders and Directors of WES during the conduct of this investigation and the preparation and publication of this report were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, US CUSTOMARY TO METRIC (SI)  
UNITS OF MEASUREMENT

US customary units of measurement used in this report can be converted to metric (SI) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
feet	0.3048	metres
feet per second	0.3048	metres per second
feet-feet per second	0.0929	metres-metres per second
feet per second per second	0.3048	metres per second per second
inches	25.5	millimetres
square feet	0.09290304	square metres

# EROSION CONTROL OF SCOUR DURING CONSTRUCTION

## FINITE--A NUMERICAL MODEL FOR COMBINED REFRACTION AND DIFFRACTION OF WAVES

### PART I: INTRODUCTION

#### Statement of the Problem

1. It is frequently necessary to construct large engineering works of improvement in the surf and nearshore zone to protect harbor entrances, recreational beaches, and navigation channels. These structures, usually built from quarried rock or precast concrete, are placed in position by crane or barge. When these major structures are erected in the coastal zone they alter the existing currents. Shallow-water surface gravity waves breaking on the new structure will cause bottom material to be suspended and transported from the region by longshore or other currents that may exist. <sup>Since</sup> This removal of material is often not compensated by an influx of additional material, and the result is a scour hole, or erosion, that usually develops along the toe of the structure.

2. In order to ensure structural stability and functional adequacy of the works of improvement, any scour area must be filled with nonerodible material (sufficiently stable to withstand the environmental forces to which it will be subjected). This may result in additional quantities of material being required during construction that can potentially lead to substantial cost overruns. To minimize potential cost increases due to scour during construction, it is necessary to quantify the probability and ultimate extent of potential scour during the scheduled construction period. This is an extremely complex problem and quantification of the probability of potential scour will likely be site-specific.

3. Since waves and wave-induced currents play an important role in producing scour near structures, it is important to predict the wave field in the vicinity of structures. Structures of interest may have complex shapes and the surrounding bathymetry may be very complex. Both long- and short-period waves may attack the structure from many different angles.

### Purpose of the Study

4. The purpose of this study is to develop a numerical model that can determine wave fields near arbitrary structures in a region of arbitrary and variable bathymetry. The model must be capable of simulating both long and short waves approaching structures from any arbitrary direction. In addition, the model must be sufficiently efficient to allow application to real coastal engineering problems.

## PART II: NUMERICAL MODEL (FINITE)

### Background

5. Short waves have wavelengths that are sufficiently short (wavelength to depth ratio less than approximately 20) that propagation speeds are a function of wave frequency. In the nearshore region, short waves with periods from a few seconds to approximately 20 sec play an important role in the movement of sediment and the stability of coastal structures.

6. Equations that govern long-wave propagation over variable depths have been known for some time (Lamb 1932). However, for shorter period waves where frequency dispersion is important, the theory has included only constant depths. Attempts have been made (Pierson 1951; Eckart 1952) to develop a two-dimensional equation for combined refraction and diffraction that would govern short-wave propagation in a region of variable depth; however, the equations developed do not reduce to the appropriate simple refraction equation after neglecting the curvature of the amplitude function and they also do not reduce to the linear long-wave equation in the case of small water depth. In recent years, Boussinesq-type equations also have been used to study the propagation of short-period waves. These equations include terms that govern both frequency dispersion and nonlinearity. Two-dimensional modeling of these equations is difficult since the frequency dispersion term is third order, therefore requiring a third-order accurate numerical scheme. Abbott, Petersen, and Skovgaard (1978) have presented a time-marching, two-dimensional, finite difference numerical model with a third-order accurate implicit solution scheme. However, a time-marching scheme requires significant computational time. In addition, the finite difference method does not realistically model a complex land-water interface as a result of the stair-step representation and has difficulties in allowing scattered waves to propagate out of a finite extent grid, since these scattered waves are not known a priori.

7. Berkhoff (1972) and Schonfeld (1972) have derived a two-dimensional wave equation that governs short-wave propagation over moderately varying depths. Smith and Sprinks (1975) gave a formal derivation of this equation. In the present study, a hybrid finite element model (FINITE) is used to solve this wave equation. The method combines a finite element solution over a finite extent region of variable depth with an analytical solution for a

surrounding infinite region of constant depth.

### Wave Equation

9. The propagation of periodic, small amplitude, surface gravity waves over a variable depth seabed of mild slope is governed by the following equation.

$$\nabla \cdot (c c_g \nabla \phi) + \frac{c}{c_g} \omega^2 \phi = 0 \quad (1)$$

where

$\nabla$  = horizontal gradient operator, dimensionless

$c$  = phase velocity, ft/sec\* =  $(g/k \tanh kh)^{1/2}$

$g$  = gravitational constant, 32.174 ft/sec<sup>2</sup>

$k$  = wave number,  $2\pi/L$ , 1/ft

$h$  = still-water depth, ft

$c_g$  = group velocity, ft/sec =  $1/2 c(1 + G)$

$G = 2k h / \sinh 2kh$ , ft/sec

$\phi$  = velocity potential defined by  $\bar{u} = \nabla \phi$ , ft<sup>2</sup>/sec

$\bar{u}$  = two-dimensional velocity vector, ft/sec

$\omega$  = angular frequency,  $2\pi/T$ , 1/sec

10. Equation 1 was derived by Berkhoff (1972) and Schonfeld (1972) and is discussed in detail by Jonsson and Brink-Kjaer (1973). This equation governs both refraction and diffraction. It reduces to the well-known "eikonal" equation governing refraction by neglect of the variation of the amplitude function in the horizontal plane. The equation reduces to the diffraction Helmholtz equation in deep or constant-depth water and to the linear long-wave equation in shallow water.

11. Finite element numerical models have been used to solve Equation 1. Berkhoff (1972, 1976) linked a finite element solution of Equation 1 over a variable depth region to a source distribution for a constant-depth outer region. However, as noted by Chen and Mei (1974), Berkhoff (1972) did not use a proper functional with the consequence that his global stiffness matrix was nonsymmetric and thus inconvenient numerically for all but the simplest problems. Bettess and Zienkiewicz (1977) also developed a finite element solution

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\* A table of factors for converting US customary units of measurements to metric (SI) units is presented on page 3.

of Equation 1. However, they used infinite elements to cover the constant-depth outer region. The shape function used in the infinite elements had an exponentially decreasing term in the direction away from the inner region. The choice of a decay length was somewhat arbitrary; but the solutions were not, in general, too sensitive to the exact value. A disadvantage of this technique is that the infinite elements increase the number of equations to be solved. If a problem requires a large number of elements because the region of interest is large and the incident wavelengths are short, this solution can require substantial computational time.

12. Equation 1 also has been solved by a parabolic approximation (Radder 1979). The approximation is derived from splitting the wave field into transmitted and reflected components and then neglecting the reflected components. This approach is applicable to some propagation problems but is not appropriate for problems involving wave interaction with coastal structures such as breakwaters.

#### Finite Element Solution

13. Equation 1 is solved by program FINITE using a hybrid finite element method originally developed by Chen and Mei (1974) to solve the diffraction Helmholtz equation in a constant-depth region. Space is divided into two regions as shown in Figure 1 (finite inner region A and infinite outer region B). Conventional finite elements are used in the variable depth region A. A single superelement is used to cover the constant-depth infinite region B. Variational principles are used that incorporate the matching conditions between the regular elements and the superelement as natural conditions. Thus a symmetric global stiffness matrix is obtained that is very advantageous for highly complex problems.

14. The variational principle for the boundary value problem requires that the following functional be stationary with respect to arbitrary first variation of the velocity potential  $\phi$  :

$$F(\phi) = \iint_A \frac{1}{2} \left[ \frac{cc}{g} (\nabla\phi)^2 - \frac{\omega^2 c}{gc} \phi^2 \right] dA \\ + \int_{\partial B_\infty} \frac{ikcc}{2g} (\phi - \phi_I)^2 dL - \int_{\partial B_\infty} \frac{cc}{g} \frac{\partial\phi_I}{\partial n} \phi dL \quad (2)$$

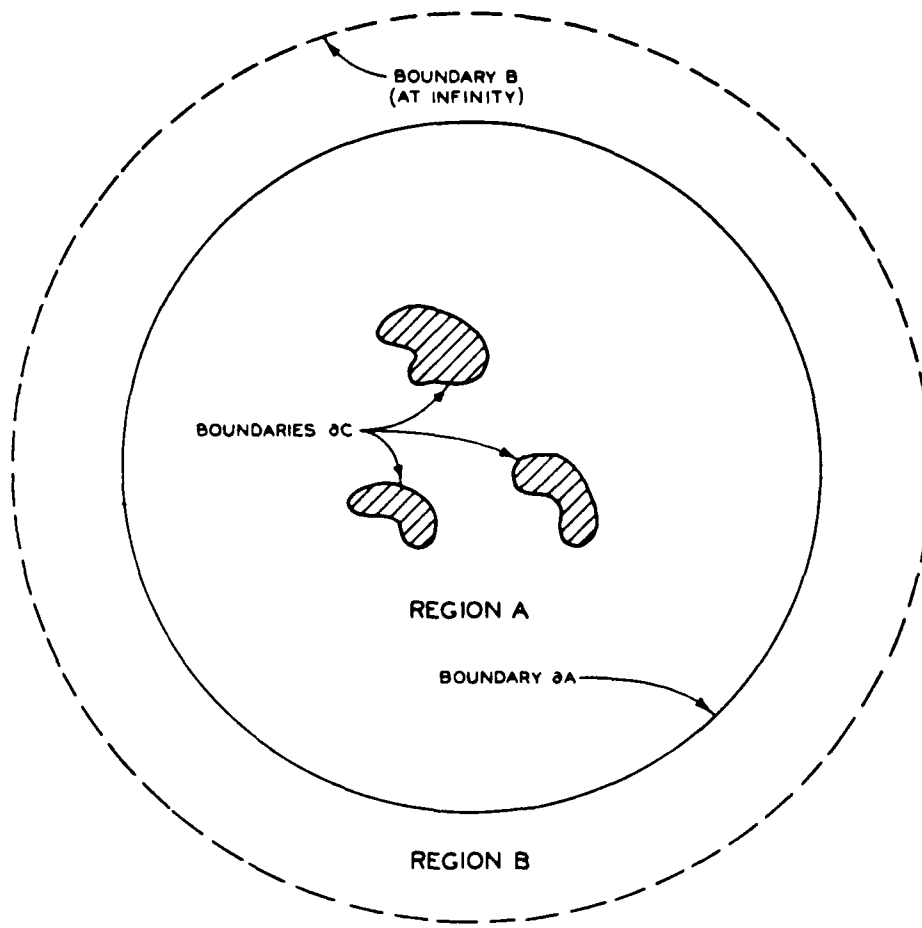


Figure 1. Regions of computation

where  $\phi_I$  and  $\phi_R$  are the incident and reflected wave velocity potentials, respectively;  $n$  is a unit normal; and the last two integrals are line integrals at infinity. Analogous to the derivation of Chen and Mei (1974), this functional can be rewritten as follows:

$$\begin{aligned}
 F(\phi) = & \iint_A \frac{1}{2} \left[ \frac{cc}{g} (\nabla \phi_A)^2 - \frac{\omega^2 c}{gc} \phi_A^2 \right] dA + \int_{\partial A} \frac{1}{2} \frac{cc}{g} (\phi_B - \phi_I) \frac{\partial(\phi_B - \phi_I)}{\partial n_A} \\
 & - \int_{\partial A} \frac{cc}{g} \phi_A \frac{\partial(\phi_R - \phi_I)}{\partial n_A} - \int_{\partial A} \frac{cc}{g} \phi_A \left| \frac{\partial \phi_I}{\partial n_A} \right. \\
 & + \int_{\partial A} \frac{cc}{g} \phi_I \frac{\partial(\phi_B - \phi_I)}{\partial n_A} + \int_{\partial A} \frac{cc}{g} \phi_I \frac{\partial \phi_I}{\partial n_A}
 \end{aligned} \quad (3)$$

where  $\phi_B$  and  $\phi_A$  are the velocity potentials in regions B and A, respectively, and  $n_A$  is a unit normal to the boundary separating regions B and A.

15. Note that all integrals are evaluated within region A or along  $\partial A$ . Thus the variational principle is a localized one. As discussed by Aranha, Mei, and Yue (1979), this variational principle can be replaced by an equivalent weak formulation.

16. The inner region A is assumed to have a variable depth and to be of finite extent. This region is subdivided into finite elements. Here the elements are triangular with simple linear shape functions. The infinite region B (or semi-infinite if a harbor located along an infinite coastline is of concern) is assumed to have a constant depth and is covered with a single superelement. Since region B has a constant depth, the governing equation is the diffraction Helmholtz equation. An analytical solution for the velocity potential in region B is well known and can be expressed as follows:

$$\phi_B = \sum_{n=0}^{\infty} H_n(kr)(\alpha_n \cos n\theta + \beta_n \sin n\theta) \quad (4)$$

where  $\alpha_n$  and  $\beta_n$  are constant and unknown coefficients,  $H_n(kr)$  is Hankel function of the first kind, and  $r$  and  $\theta$  are radial and angular variables in polar coordinates. For a semi-infinite region B and a straight infinite coastline,  $\phi_B$  can be expressed as follows:

$$\phi_B = \sum_{n=0}^{\infty} \alpha_n H_n(kr) \cos n\theta \quad (5)$$

The velocity potentials given in Equations 4 and 5 satisfy the Sommerfeld radiation condition that the scattered waves must behave as outgoing waves at infinity. Thus region B can be considered to be a single superelement with shape function given by Equations 4 and 5.

17. If the shape functions are used to evaluate the integrals of Equation 3 and the functional is extremized with respect to the unknowns, a set of linear algebraic equations is obtained. Of course, the infinite series given by Equations 4 and 5 must be truncated at some finite extent. The number of terms that must be retained depends upon the incident wavelength and may be found by increasing the number of terms until the solution is insensitive to



the addition of further terms. Solution of the boundary value problem thus reduces to the solution of  $N$  linear algebraic equations for  $N$  unknowns (where  $N$  is the number of node points in the finite element discretization plus the number of unknowns in the truncated series). That is,

$$\begin{matrix} [K] & \{\psi\} & = & \{Q\} \\ N \times N & N \times 1 & & N \times 1 \end{matrix} \quad (6)$$

The symmetric complex coefficient matrix  $[K]$  is in general large, sparse, and banded. It can be stored and manipulated in the computer in a packed form (Chen and Mei 1974). The packed form is chosen to be a rectangular array ( $N$  variables in length and the semibandwidth in width). Only elements of  $[K]$  on and above the diagonal and within the band width need to be stored in the packed form.

18. Although the packed form of  $[K]$  greatly reduces the required computer memory, the problems discussed later are so large that even memory requirements of the packed form of  $[K]$  are excessive. However, since the symmetric coefficient matrix is positive definite, a solution is possible by elimination methods without pivoting. Without pivoting, elimination performed using one row affects only the triangle of elements within the band below that row. Thus the packed form of  $[K]$  can be partitioned into several smaller blocks. Using Gaussian elimination, only two blocks at a time are involved in the reduction and back substitution with the remainder of the blocks kept in peripheral storage. This technique allows the solution of extremely large matrices.

### Verification

19. To verify this numerical model, comparisons were made between the finite element calculations and both an analytical and a numerical solution for the interaction of waves with a circular island on a paraboloidal shoal. Figure 2 is a sketch of the problem. Hom-ma (1950) presented the analytical solution to the long-wave equation for plane waves incident upon this island.

20. Many investigators, including Berkhoff (1972, 1976) and Bettess and Zienkiewicz (1977), have compared their finite element solutions of the long-wave equation with Hom-ma's solution. For example, Berkhoff (1972, 1976) used 156 elements to cover the paraboloidal shoal (actually one-half of the

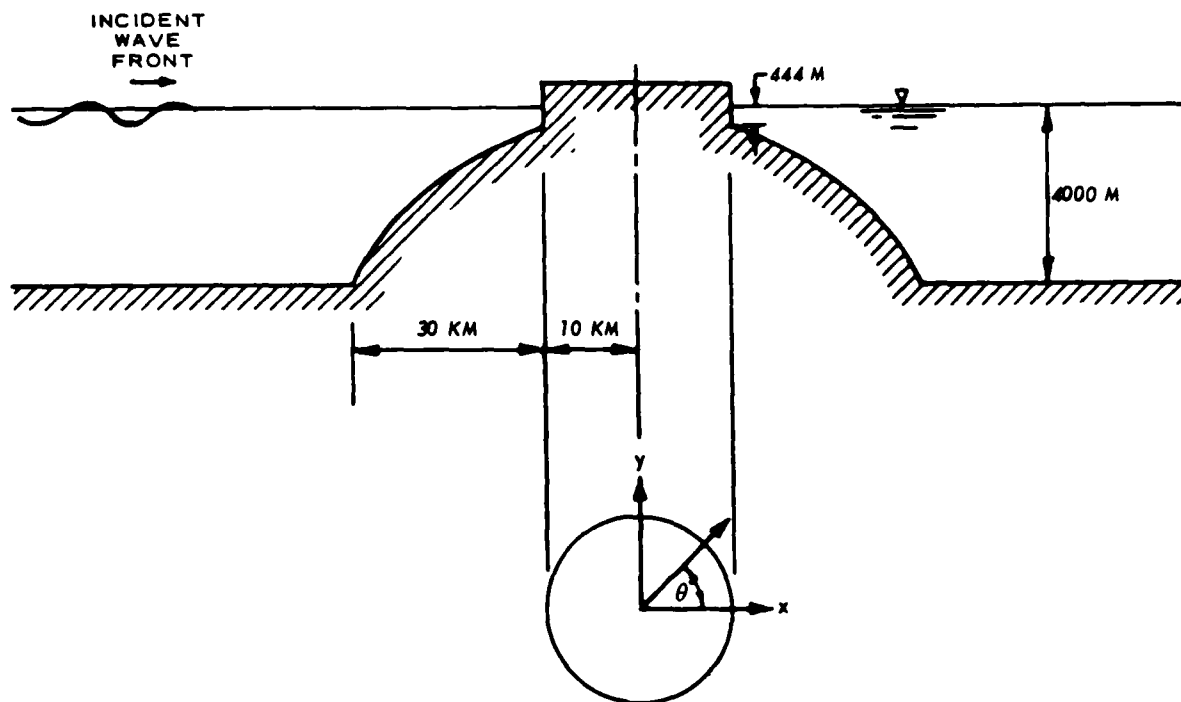


Figure 2. Circular island on a paraboloidal shoal

shoal since by symmetry the solution required calculations for just one-half of the shoal). This number of elements was not sufficient to adequately resolve features of the problem; consequently, Berkhoff's finite element solution differed from Homma's analytical solution by as much as 70 percent at one location. Since Berkhoff did not attempt to use a finer grid, it is likely that his coarse grid required a moderate computational time. The model described in this paper would require less than 0.1 sec of computational time on a CRAY-1 computer to solve Equation 6 using Berkhoff's grid. Bettess and Zienkiewicz (1977) also used a fairly coarse grid similar to Berkhoff's grid.

21. Lautenbacher (1970) used an integral equation solution to solve the long-wave equation for waves interacting with a circular island on a shoal with linear side slopes. He used a coarse circular mesh grid with only 130 points. Because the resulting coefficient matrix was full, the computational time required for a solution was 60 min on an IBM 7094 computer.

22. Figure 3 shows a finite element grid with 2,640 elements used by the model described in this report to solve the problem of the interaction of long waves with a circular island on a paraboloidal shoal (by symmetry only

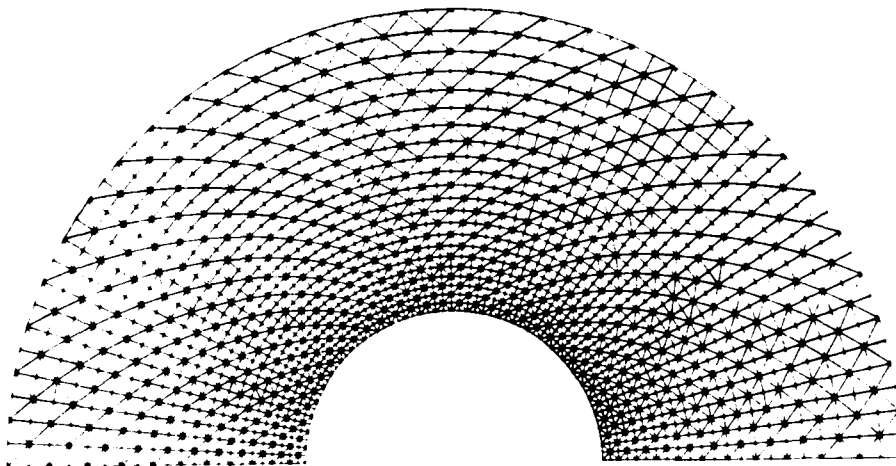


Figure 3. Finite element grid for paraboloidal island  
(2,640 elements)

half the shoal needs to be considered). Figure 4 shows comparisons between Hom-ma's analytical solution and the finite element model solution for incident waves with five different periods. The agreement is excellent with only slight differences for the 240-sec waves (resulting from lower resolution of the incident wave for shorter period waves). The computational time for solution is approximately 4 sec on a CRAY-1 computer.

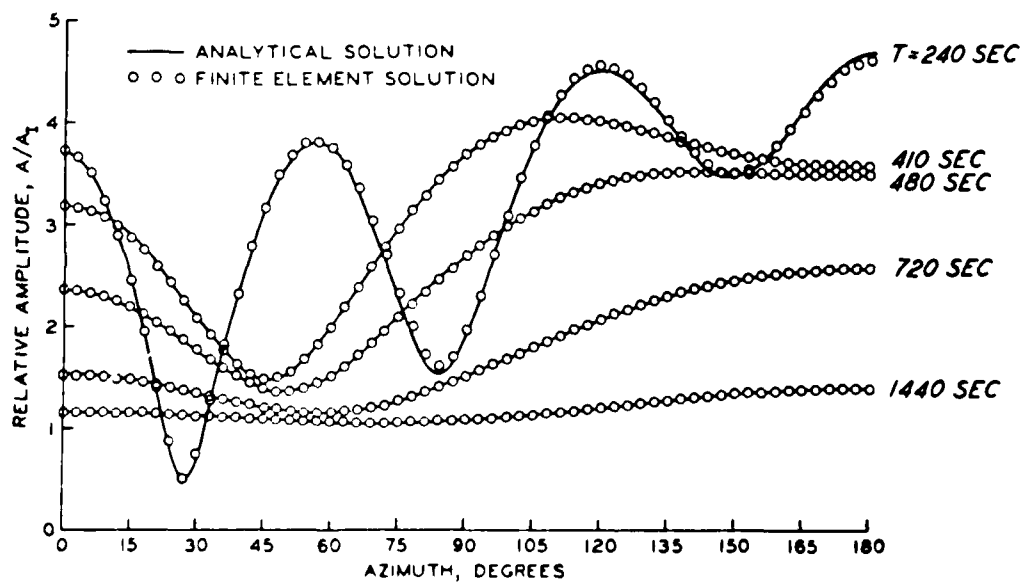


Figure 4. Solutions without dispersion (2,640 element grid)

23. Jonsson, Skovgaard, and Brink-Kjaer (1976) show that for a wave with a 240-sec period interacting with the circular island on a paraboloidal shoal the effect of frequency dispersion is not particularly significant. The ratio of wavelength to water depth for this case is approximately 11. However, for a 120-sec incident wave (wavelength to water depth ratio of less than 5), frequency dispersion is quite significant. In order to maintain a resolution of a 120-sec wave that is approximately equal to that obtained for the 240-sec wave using the 2,640-element grid, it is necessary to reduce element side lengths by a factor of approximately 2. This reduction results in a quadrupling of the number of elements. Figure 5 shows a finite element grid with 10,560 elements used to calculate the interaction of a 120-sec wave with the island.

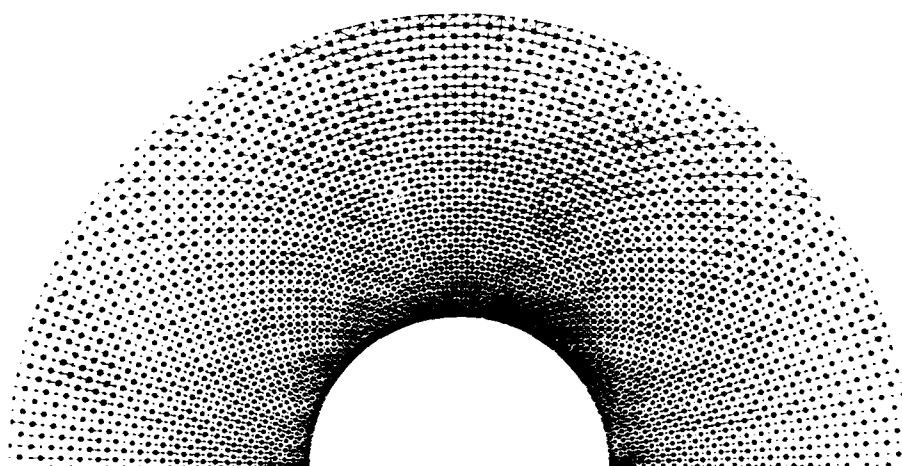


Figure 5. Finite element grid for paraboloidal island (10,560 elements)

24. Figure 6 shows a comparison between the analytical solution of the long-wave equation by Hom-ma (1950) and the finite element solution (grid of Figure 5) for a 120-sec incident wave. Figure 7 also shows a comparison between a numerical solution of Equation 1 using an orthogonal collocation solution and the finite element model solution of this report. In both cases there is excellent agreement. The effect of frequency dispersion is quite significant as shown in Figure 8, where the solutions of the long-wave equation and Equation 1 are overlapped. In fact, the inclusion of frequency dispersion is much more significant a factor than is resolution of the wave form for this particular case. For example, Figure 9 shows a solution including dispersion using the 2,640-element grid. The agreement between the finite element and

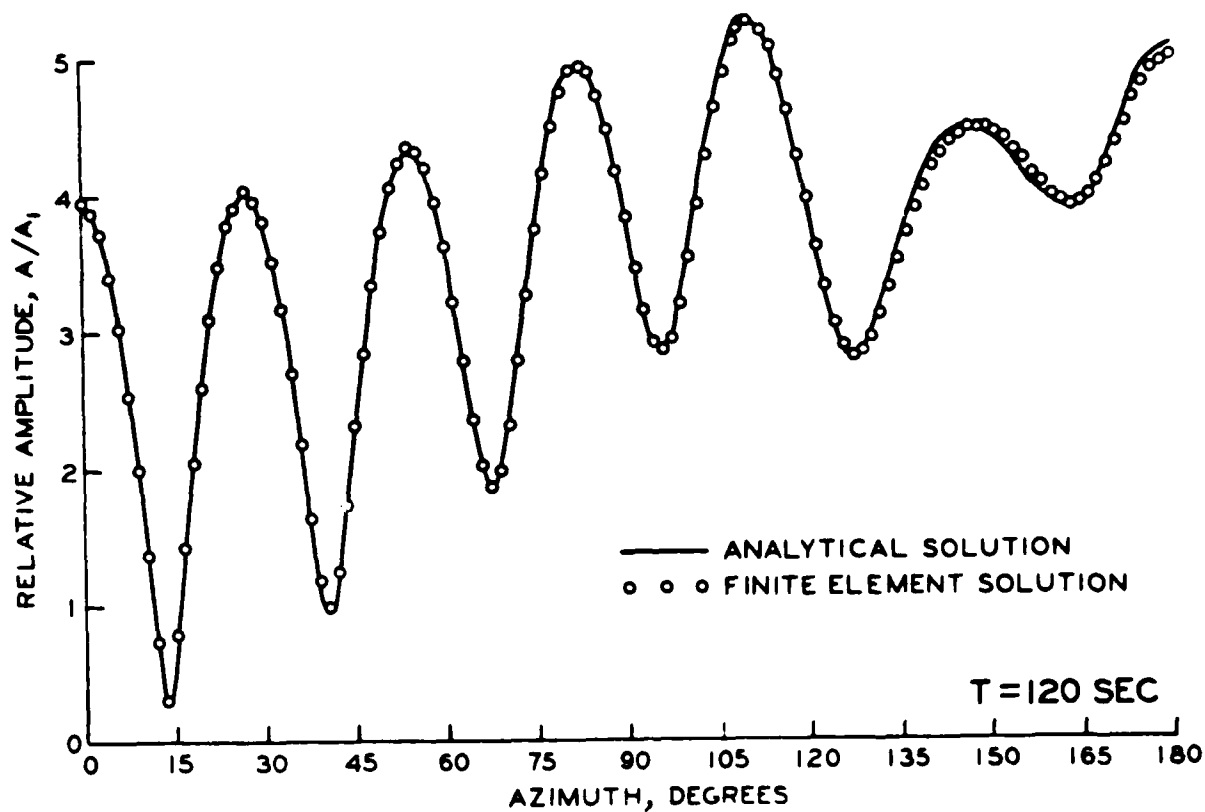


Figure 6. Solutions without dispersion (10,560-element grid)

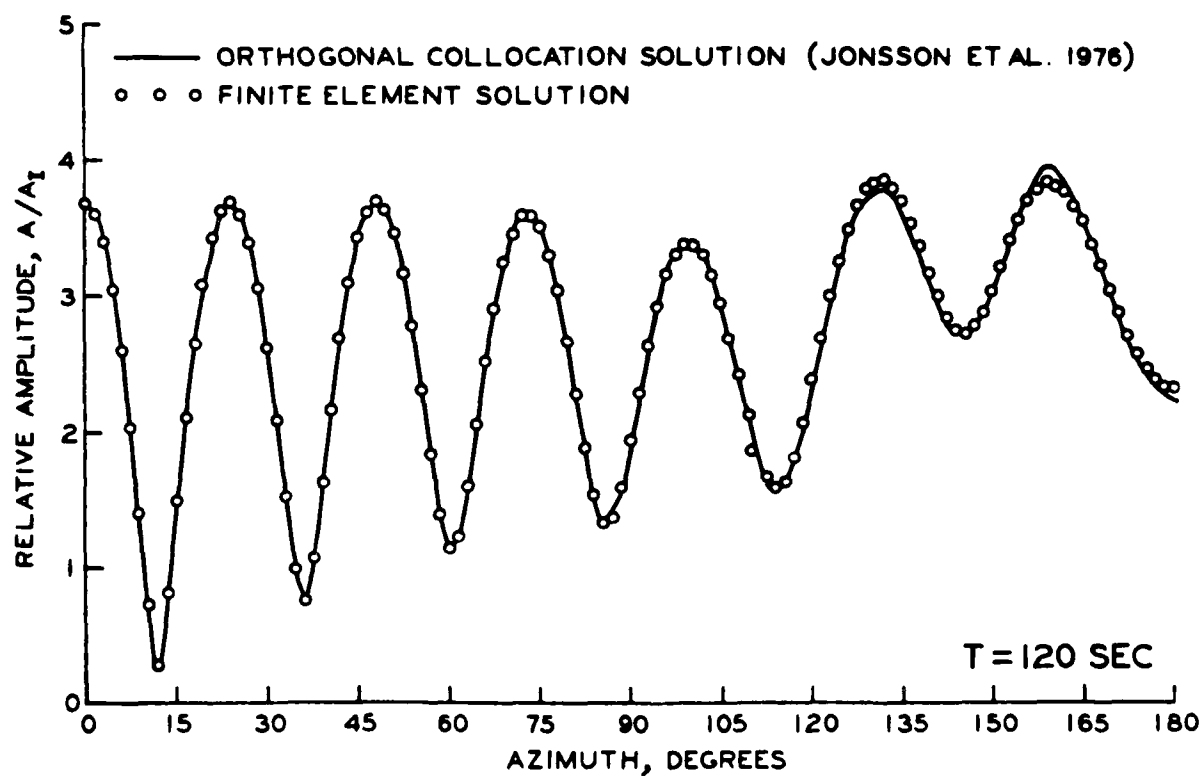


Figure 7. Solutions with dispersion (10,560-element grid)

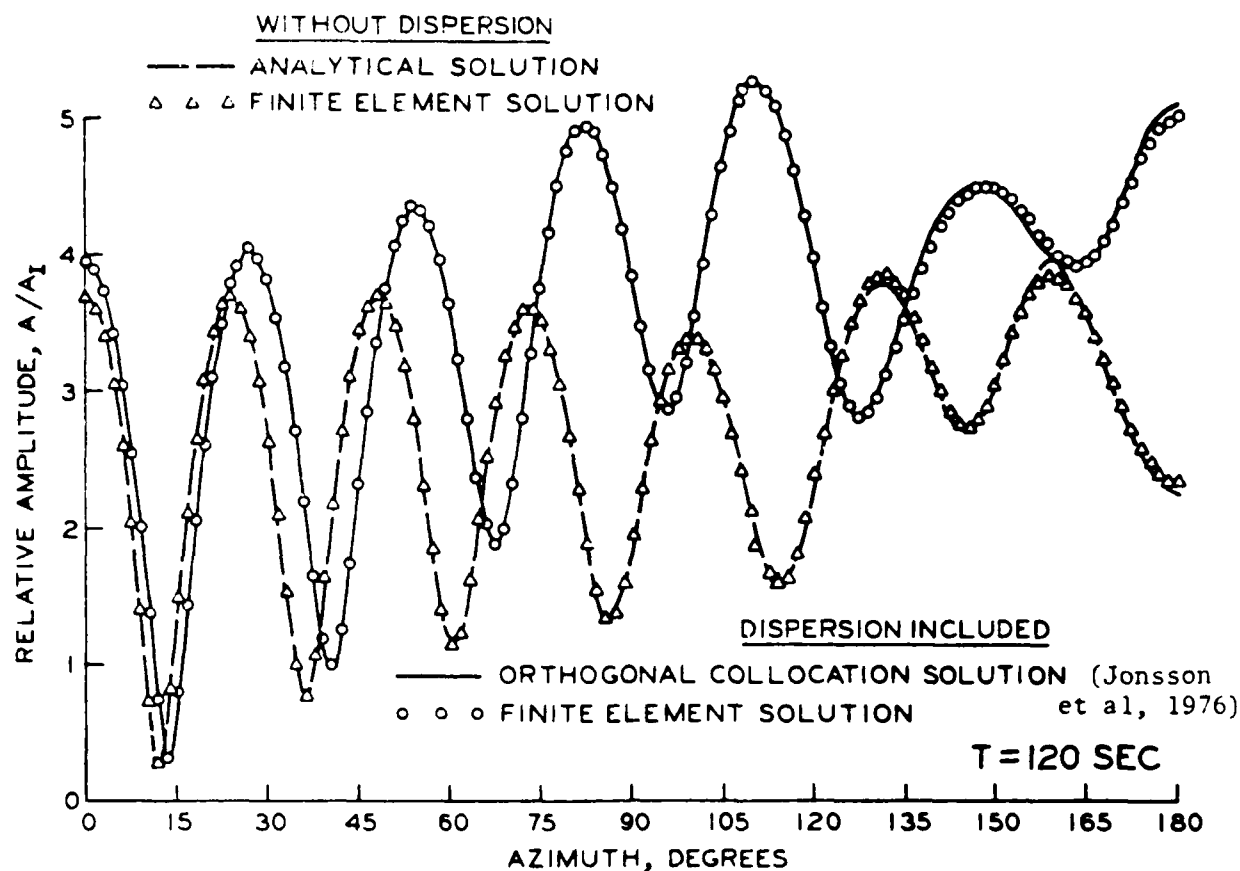


Figure 8. Effect of dispersion

collocation solutions is much better using the 2,640-element grid and including dispersion than is obtained using the 10,560-element grid without dispersion.

25. The computational time requirement to solve a problem using the 10,560-element grid is less than 1 min on a CRAY-1. This is extremely modest considering the very large size of this finite element grid. The computational time of the model is proportional to the number of nodes times the bandwidth of the coefficient matrix squared. This grid has more than 50 times the number of nodes contained in the grid used by Berkhoff (1972, 1976) and a bandwidth approximately 3.3 times greater. Thus the computational time requirement is almost 600 times greater for this grid than for Berkhoff's grid. The computer memory requirements also are very modest as a result of the partitioning of the coefficient matrix. Although the packed form of the coefficient matrix had approximately 1.7 million terms for this problem, only 45,000 terms were in central memory at any given time with the remainder in peripheral storage.

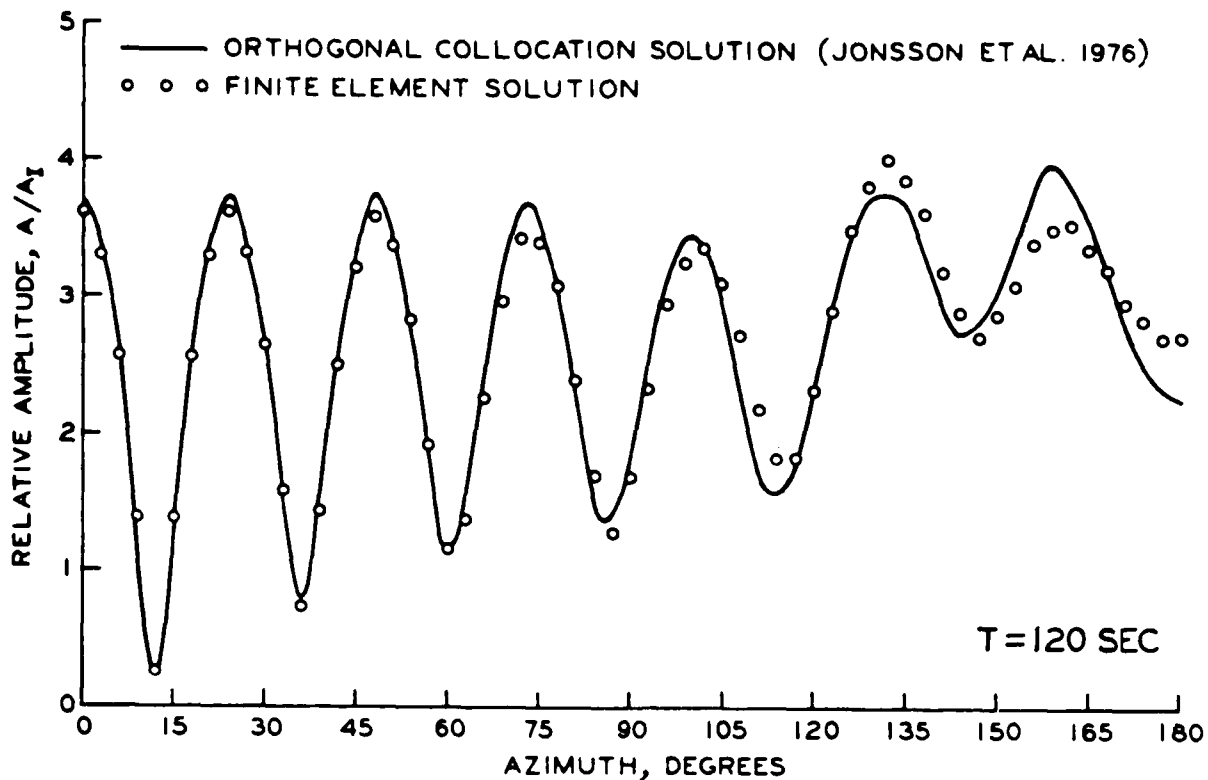


Figure 9. Solutions with dispersion (2,640-element grid)

#### Comparison with Three-Dimensional Numerical Model

26. Equation 1 was derived assuming that the bathymetry was slowly varying. This mild slope approximation is valid for the slow bathymetric variations of the paraboloidal shoal shown in Figure 2. However, the approximation is not appropriate for many practical problems involving the interaction of waves with man-made structures. For these problems, it is necessary to use a fully three-dimensional model such as the hybrid three-dimensional finite element developed by Yue, Chen, and Mei (1976). Of course, a three-dimensional model requires substantial computational time. Therefore it is of interest to consider how well a two-dimensional mild-slope model compares with a three-dimensional model for a problem where the mild-slope approximation is strongly violated.

27. Yue, Chen, and Mei (1976) used a three-dimensional model to consider the interaction of small amplitude plane waves with an elliptic island on a circular base. Figure 10 illustrates the problem and shows the finite

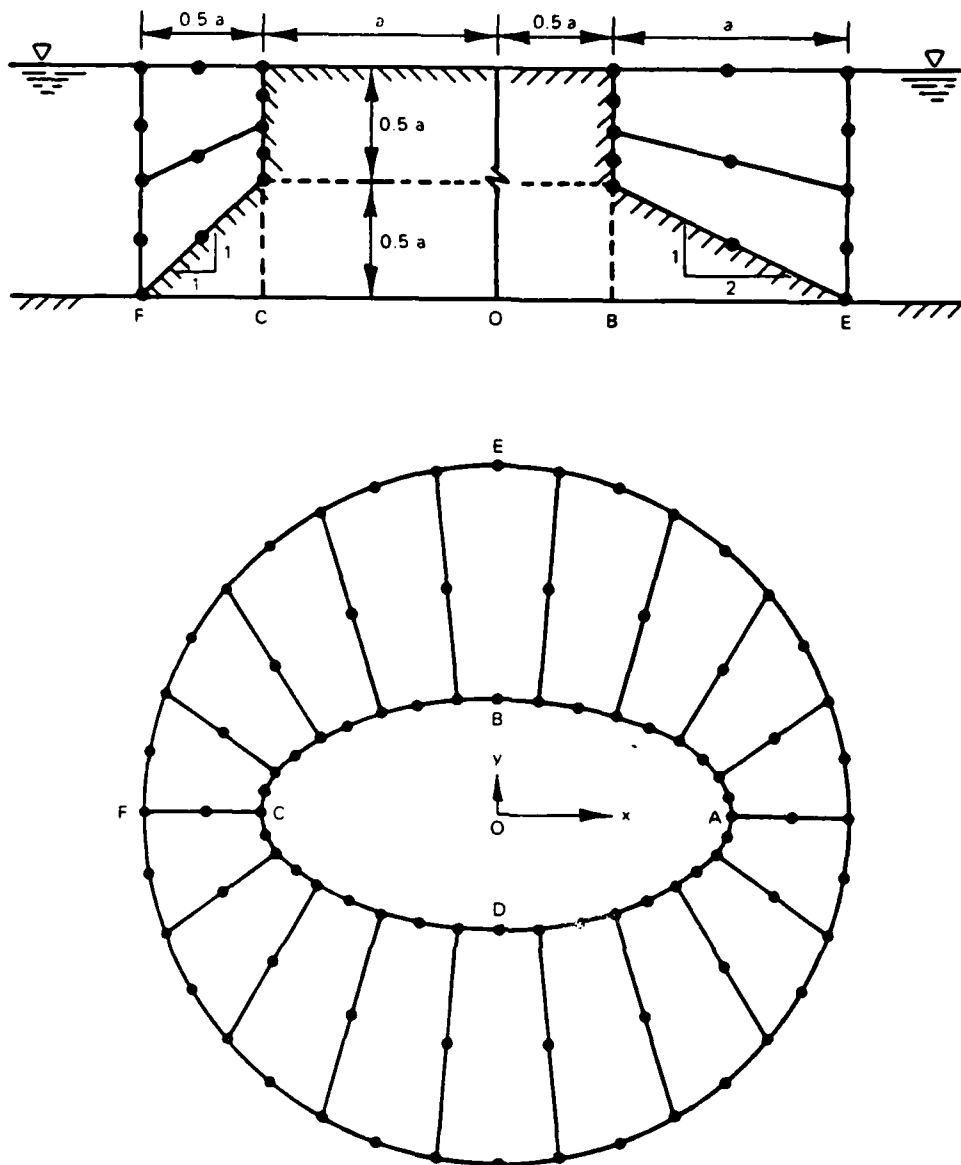


Figure 10. Elliptic island and three-dimensional grid

element grid used by Yue, Chen, and Mei (1976). Bottom side slopes vary from 1V on 1H to 1V on 2H and violate the mild-slope assumption.

28. Figure 11 shows the two-dimensional finite element grid used by the model described in this report to simulate the interaction of small amplitude plane waves with the elliptical island. Figures 12 and 13 show the interaction of waves ( $k_0 a = 1$  and two incident directions) with the elliptical island. The amplification factors and phases around the elliptical island calculated by the three-dimensional model of Yue, Chen, and Mei (1976) and the



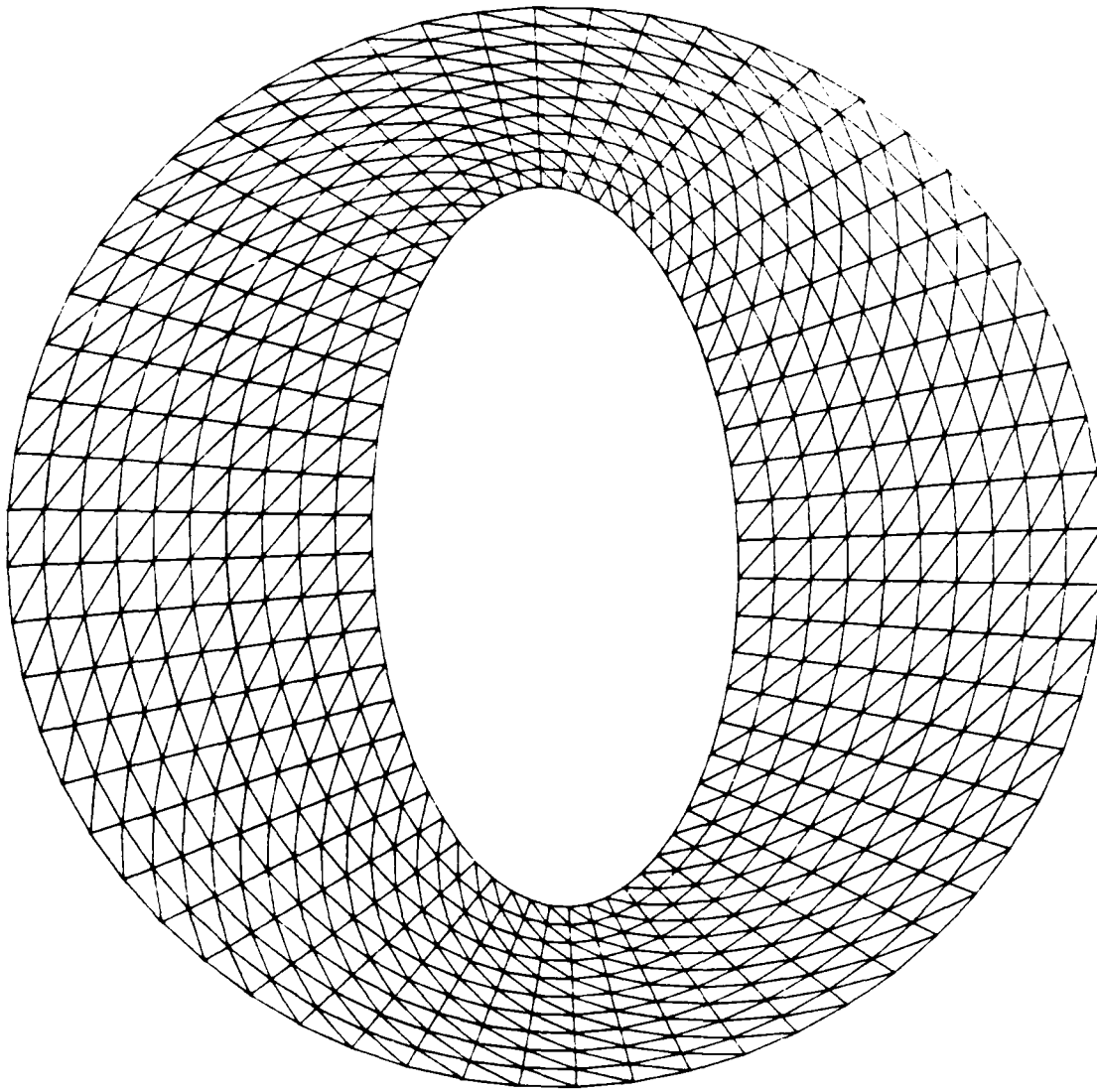


Figure 11. Finite element grid for elliptical island

two-dimensional model described in this report are shown. The maximum difference in amplification factors is not much greater than 10 percent. Similar agreement was found for greater values of  $k_0 a$ .

29. Although the two-dimensional model cannot perfectly reproduce the three-dimensional model results, the difference may be within the accuracy requirements of many engineering applications. Of course, the computational requirements of the two-dimensional model are very modest compared with the requirements of the three-dimensional model. For the problem of waves interacting with the elliptical island, the three-dimensional model required 2.6 min of computational time on an IBM 370/168 computer for each wave period. The

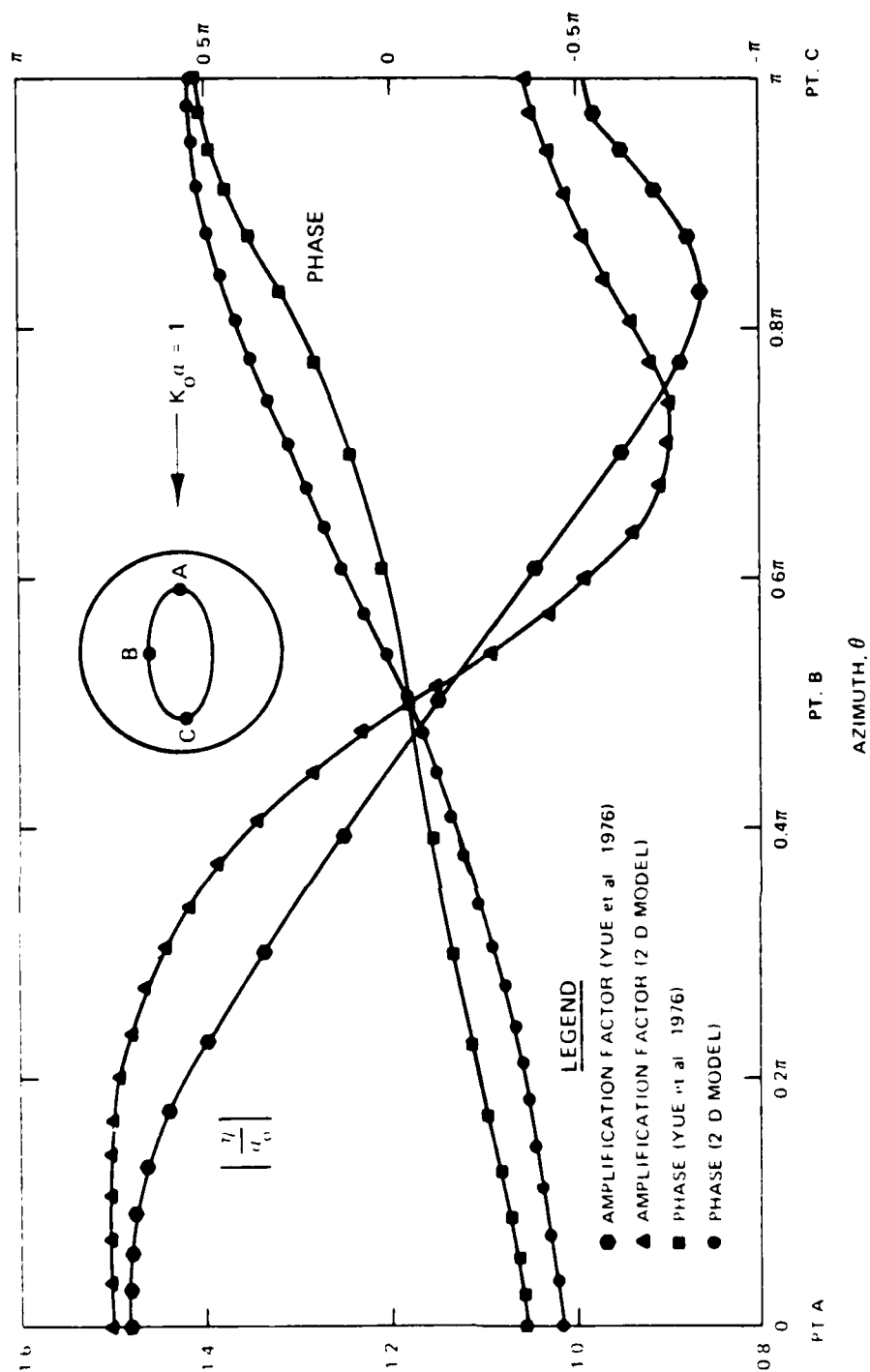


Figure 12. Comparison of model results (incident azimuth  $0$ )

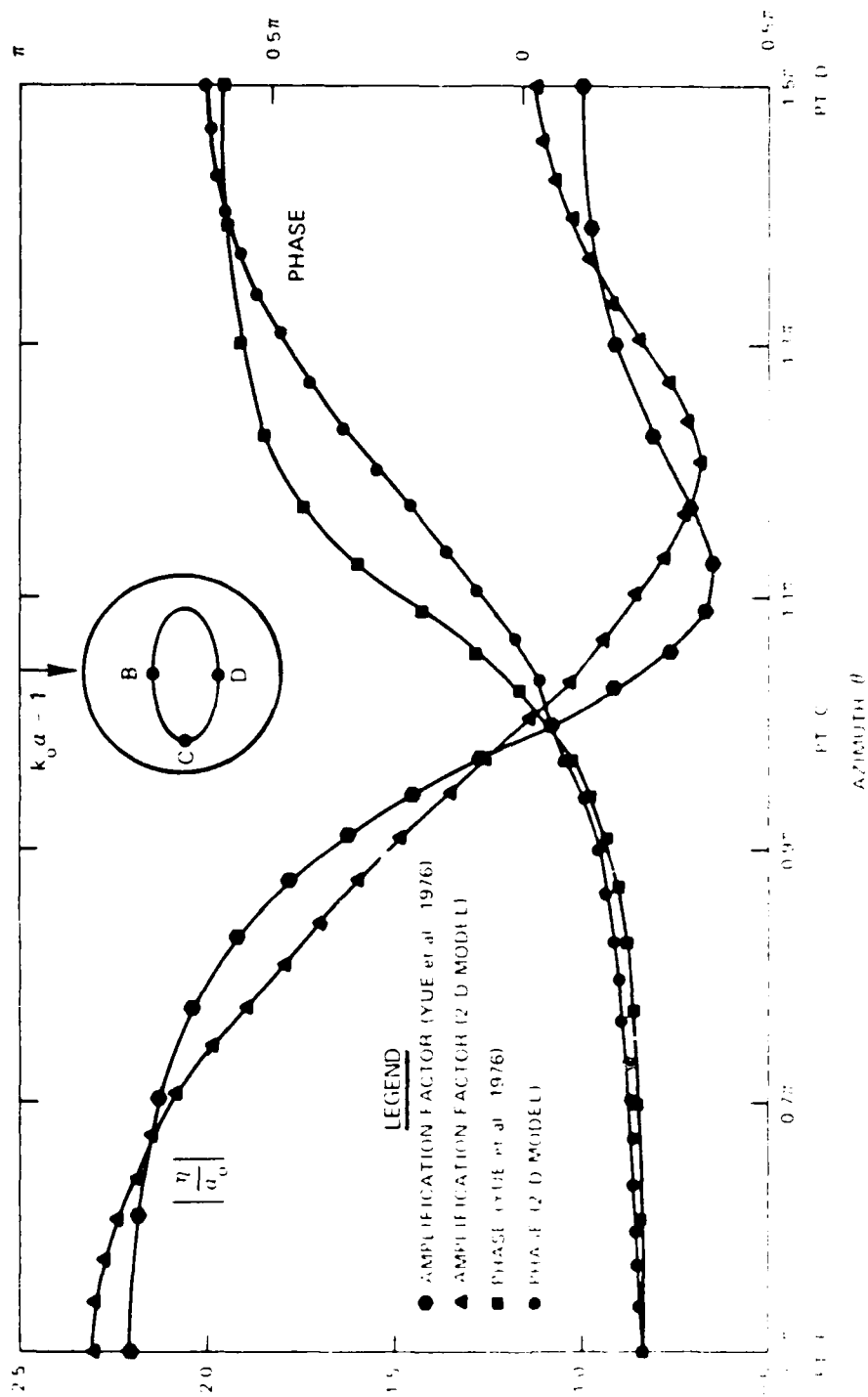


Figure 13. Comparison of model results (conducted at azimuth 90°)

two-dimensional model required less than 2 sec of computational time on a CRAY-1 computer. Part of the difference in computational time is a consequence of the unknown relative speeds of the two computers.

30. The difference in computational time of the two- and three-dimensional models becomes more significant for larger problems. For example, Yue, Chen, and Mei (1976) estimate that approximately 6 hr of computational time on an IBM 370/168 computer would be necessary to calculate the interaction of a wave with a period of 8.5 sec or greater with a particular offshore harbor. If a resolution of 10 grid points per wavelength is maintained, the two-dimensional model would require an estimated computational time of only 0.5 to 1 min to perform the same calculation on a CRAY-1 computer.

#### Comparison with Laboratory Experiments

31. Putnam and Arthur (1948) performed the pioneering laboratory experiments that considered diffracted waves in the lee of an impermeable breakwater located in constant-depth water. Mobarek (1962) performed similar experiments except that a linear bottom slope was used in the lee of the breakwater and a very small model (72 ft<sup>2</sup>) was used. In order to study the phenomenon of combined refraction and diffraction near structures, laboratory experiments were performed by Hales (1980). In these experiments an impermeable breakwater was located perpendicular to a straight coastline. A linear bottom slope extended from some distance in front of the breakwater to the shoreline.

32. The laboratory facility used in these tests covered an area of approximately 2,500 ft<sup>2</sup>. The breakwater was 15 ft long and 1 in. thick. The water depth in the facility decreased from 1.0 ft to 0.0 ft over a distance of 20 ft. The sidewalls that laterally bounded the facility were curved to follow wave orthogonals. A plunger-type wave maker was used to generate small amplitude sinusoidal waves that approached the breakwater at an angle. An array of 32 parallel-wire, resistance-type sensors was used to measure the waves. The gages were supported by a large stand so that only the measuring wires of the gages were in the water (i.e., the gages did not require individual feet for support). Information was recorded and analyzed by a minicomputer.

33. One problem in simulating these laboratory tests numerically is that the waves break in the hydraulic model near the shoreline and thus dissipate

their energy. There is no mechanism to dissipate energy in the numerical model described in this paper. However, dissipation can be simulated by allowing waves to continue to propagate out of the problem area. Figure 14 illustrates schematically how this is done. The breakwater and the linear slope are numerically modeled only to the point where breaking occurs. The depth is

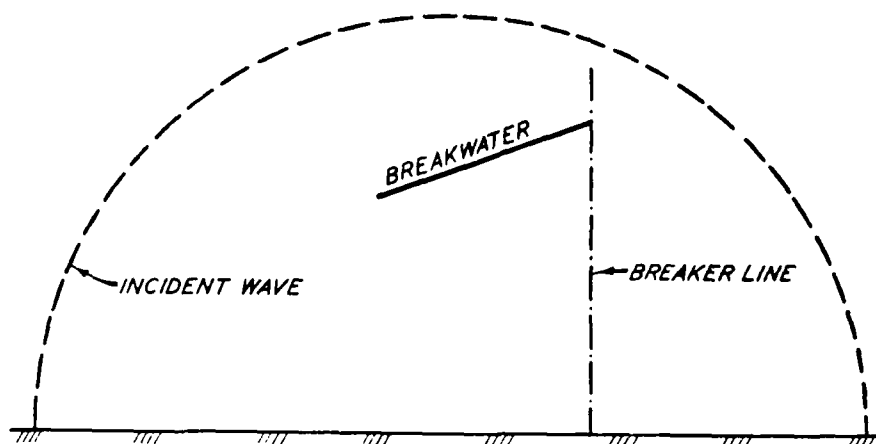


Figure 14. Wave interaction with impermeable breakwater

then increased to the depth of the semi-infinite region surrounding the inner region and the waves are allowed to radiate away from the inner region. Figure 15 shows the finite element grid used for this simulation.

34. Figure 16 shows a typical comparison between the laboratory measurements and the finite element calculations. Also shown is a uniformly valid asymptotic solution derived recently by Liu and Lozano (1979). The solution derived by Liu and Lozano (1979) is in excellent agreement with the laboratory tests. The finite element calculations agree quite well in the shadow zone with the laboratory tests. The agreement is not as good outside the shadow zone. The difference probably is attributable to the artificial increase in depth to allow the waves to radiate from the inner region. This depth transition would cause some energy to reflect back into the inner region.

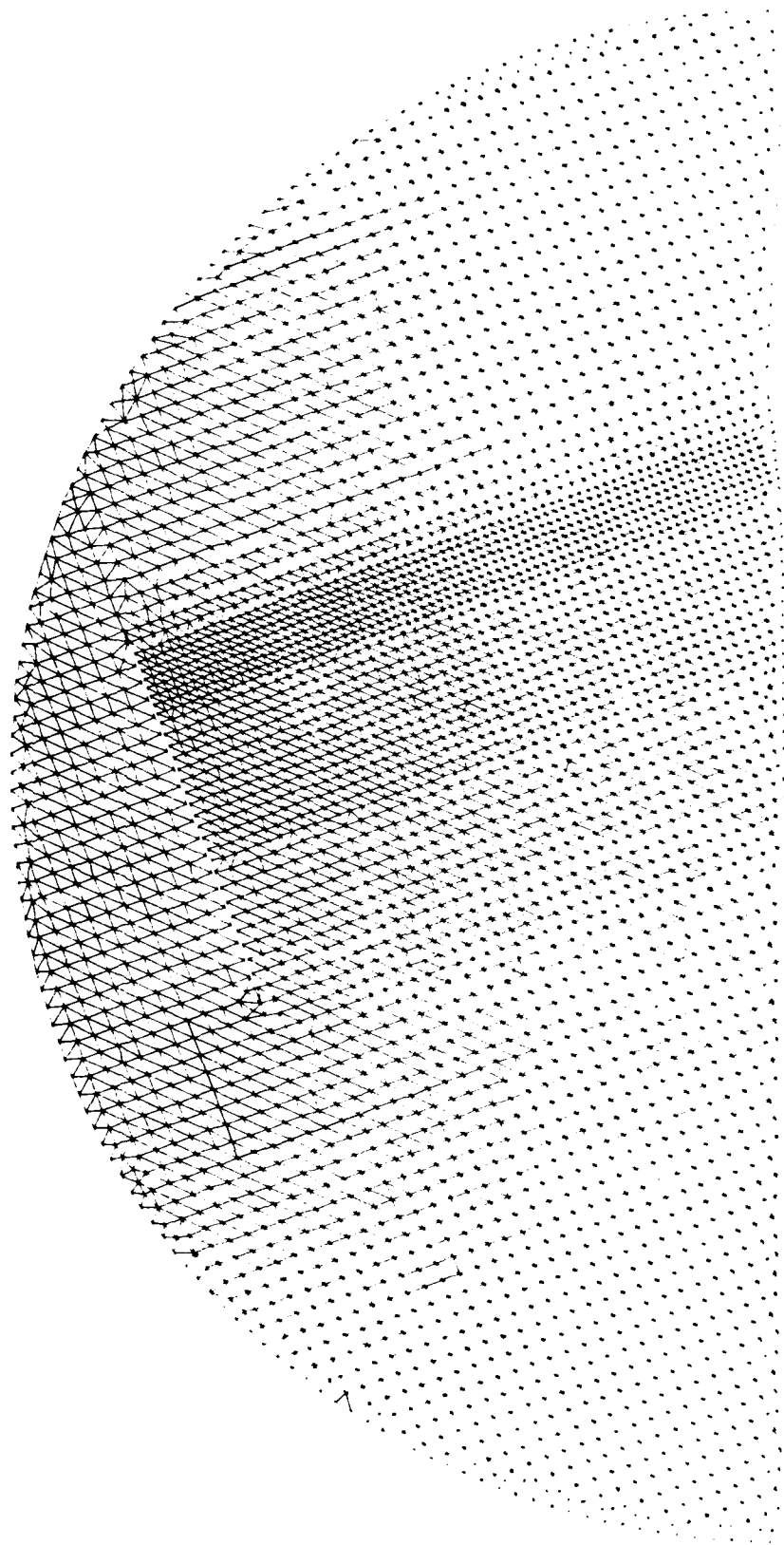


Figure 15. Finite element grid for wave interaction with breakwater

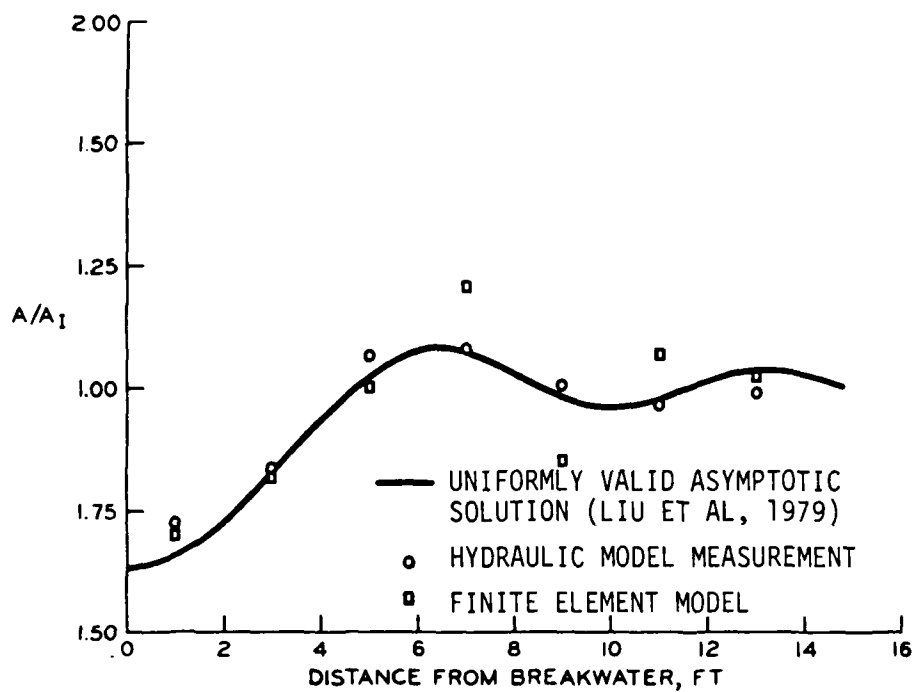


Figure 16. Comparison with laboratory experiments

### PART III: INPUT DATA PREPARATION FOR FINITE ELEMENT SOLUTION

35. The following example problem is presented to demonstrate the steps and procedures for preparing a finite element grid to be used for the numerical model solution of combined refraction and diffraction. This example outlines the methodology for data manipulation on the computer facilities at the US Army Engineer Waterways Experiment Station (WES).

#### Data Preparation for Computer Plotting

36. Assume it has been determined that an area of interest such as outlined in Figure 17 is required to be digitized for computer processing of the

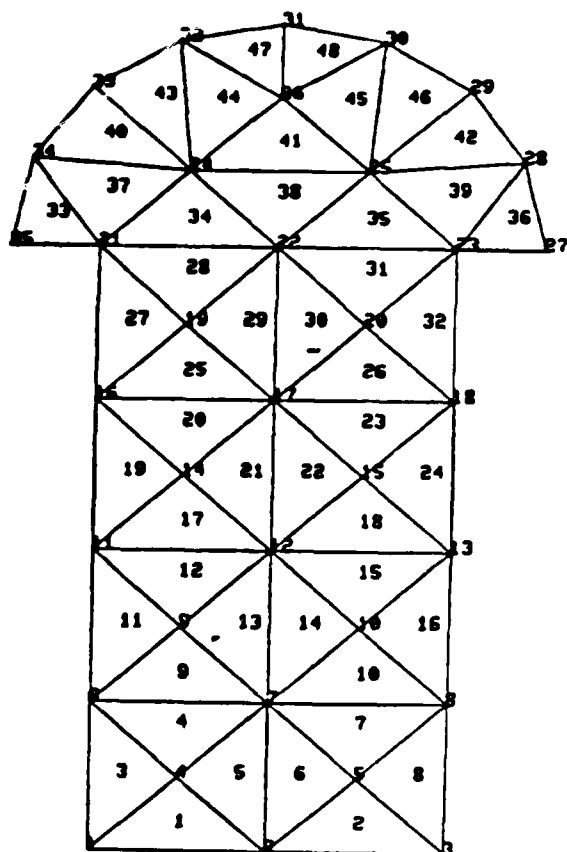


Figure 17. Example problem for demonstrating the preparation of input data for hybrid finite model

hybrid finite element model. The initial determinations after the overall region has been delineated include an orientation so that the elements of the grid can be numbered in continuous fashion. Also, the nodes of the elements should be numbered in a continuous fashion (counterclockwise). The x and y coordinates of each node of the elements are digitized in continuous fashion and recorded for verification later. If the program CONVER is used for converting the measurement of digitized x and y coordinates to prototype units, it is necessary that all x and y values be positive. When the grid has been digitized on magnetic tape, the tape is assigned a number for relocation later.

37. To convert the digitized ASCII tape to BCD tape, run program DIG1 (Figure 18). The steps for performing such an operation include:



```

OLD DIG1
*LIST
1088N
208:IDENT:USERID,USER NAME
408:OPTION:FORTRAN
608:FORMAT:ASCII
PROGRAM TO CONVERT ASCII TAPES FROM DIGITIZER TO BCD TAPES
70C
CHARACTER*6 X(275),Y(275)
80
CHARACTER*5 B5 '/'
90
CHARACTER*1 SGN1(275),SGN2(275)
100
CHARACTER SGN*1(2) /'.','.'/
110
CHARACTER Z*68 /'.','.'/
120
CHARACTER Z*68 /'.','.'/
130
1
CALL FNMEDIA(3,0)
135
NREC=0
140
150
10 NRECS=NREC
160
PRINT 900
170
FORMAT (1H1)
180
DO 5 I=1,275
190
K=1
200
READ (1,100,END=99) SGN1(I),X(I),SGN2(I),Y(I)
210
FORMAT (2(A1,A5))
220
NREC=NREC+1
230
WRITE (3,300) SGN1(I),X(I),SGN2(I),Y(I),Z
240
300
FORMAT (2(A1,A5),A68)
250
5
CONTINUE
270
DO 15 I=1,55
280
N=NRECS+1
290
N1=N+55
300
N2=N+55
310
N3=N+55
320
N4=N+55
330
J1=1+55
340
J2=1+110
350
J3=1+165
360
J4=1+220
370
PRINT 200,N,SGN1(I),X(I),SGN2(I),Y(I),
380
1 N1,SGN1(J1),X(J1),SGN2(J1),Y(J1),
390
2 N2,SGN1(J2),X(J2),SGN2(J2),Y(J2),
400

```

```

410
3 N3,SGN1(J3),X(J3),SGN2(J3),Y(J3),
420
4 N4,SGN1(J4),X(J4),SGN2(J4),Y(J4)
430
200
FORMAT (5(GX,17,2H*,2(A1,A5)))
440
15
CONTINUE
450
GO TO 10
460
99
DO 20 I=K,275
470
SGN1(I)=SGN2(I)
480
X(I)=B5
490
SGN2(I)=SGN2(I)
500
Y(I)=B5
510
20
CONTINUE
520
DO 25 I=1,55
530
N=NRECS+1
540
N1=N+55
550
N2=N+55
560
N3=N+55
570
N4=N+55
580
J1=1+55
590
J2=1+110
600
J3=1+165
610
J4=1+220
620
PRINT 200,N,SGN1(I),X(I),SGN2(I),Y(I),
630
1 N1,SGN1(J1),X(J1),SGN2(J1),Y(J1),
640
2 N2,SGN1(J2),X(J2),SGN2(J2),Y(J2),
650
3 N3,SGN1(J3),X(J3),SGN2(J3),Y(J3),
660
4 N4,SGN1(J4),X(J4),SGN2(J4),Y(J4)
670
25
CONTINUE
680
STOP
690
END
7008:EXECUTE
7108:LIMITS:30,15K,,20K
7208:TAPES:01,X1D,,TAFEND,,ASCII TAPE NAME,,DENB
7258:FFILE:01,HLABEL,ASA9,FXLNG/4,NSER
7308:FFILE:03,MOSLEW
7408:TAPES:03,X3D,,BCD TAPE NAME
7508:MSG2:SAVE 03,USER NAME,USERID,BCD TAPE NAME
7808:ENDJOB

```

Figure 18. Program DIG1 to convert digitized ASCII tape to BCD tape

- a. Sign on DPS1 Honeywell System at WES. The telephone numbers for both 300 Baud and 1200 Baud are 2162, 2171, 3561, and 3571.
- b. Type in  
OLD ROHH314/DIG1,R  
CLEAR  
SAVE DIG1
- c. Type in  
EDIT  
The system will respond with a "-".
- d. Type in "PS:/IDENT/" after the "-".  
The system will search and print the line containing the character string "ident" as:  
20\$:IDENT:USERID,USERNAME
- e. Type in  
RVS:/USERID,USERNAME/://YOUR USER ID, YOUR NAME/  
The system will replace the old user's ID and user's NAME by the new user's ID and NAME, as desired.
- f. Type in  
PS:/720/  
The system will respond with  
720\$:TAPE9:01,X1D,,TAPENO,,ASCII TAPE NAME,,DEN8
- g. Type in  
RVS:/TAPENO,,ASCII TAPE NAME,,DEN8/://ACTUAL TAPE NO,,ACTUAL  
ASCII TAPE NAME,,DENSITY OF THE TAPE/  
where TAPENO has been previously assigned to the digitized magnetic tape. ASCII TAPE NAME can be (1-8) arbitrary alpha-numeric characters. Parameter DEN8 specified 800 density while DEN16 indicates 1600 density.
- h. Type in  
PS:/740/  
The system will respond with  
740\$:TAPE9:03,X3D,,,,BCD TAPE NAME
- i. Type in  
RVS:/BCD TAPE NAME/://ACTUAL BCD TAPE NAME/
- j. Type in  
PS:/750/  
The system will respond with  
750\$:MSG2:save 03,USER NAME,USERID,BCD TAPE NAME
- k. Type in  
RVS:/USER NAME,USERID,BCD TAPE NAME/://YOUR NAME,YOUR ID,ACTUAL  
BCD TAPE NAME/  
(Note: BCD TAPE NAME should be the same name as that used in Line 740.)
- l. Type in  
RESAVE DIG1  
The system will respond with  
DATA SAVED - DIG1  
End of file

- m. Type in  
DONE  
The system will respond with a "\*" (CARDIN MODE) and wait for the next command.
- n. Type in  
RUN  
The system will respond with  
SNUMB XXXOXT

38. The BCD tape contents will be saved as a permanent file by running program TP2FIL (Figure 19) in the following manner.

- a. Sign on the DPS1 computer at WES
- b. Type in  
OLD ROHH314/TP2FIL,R  
CLEAR  
SAVE TP2FIL
- c. Type in  
EDIT
- d. Type in  
PS:/IDNET/
- e. Replace USERID and USER NAME with actual user's ID and user's NAME  
Type in  
RVS:/USERID,USER NAME/;/ACTUAL USER'S ID, USER'S NAME/
- f. Type in  
PS:/60/  
The system will respond with  
60\$:TAPE9:F1,X1D,,BCD TAPENO,,BCD TAPE NAME
- g. Type in  
RVS:/BCD TAPENO,,BCD TAPE NAME/;/ACTUAL BCD TAPE NUMBER,,ACTUAL BCD TAPE NAME/  
(Note: The BCD TAPE NUMBER is obtained from the log file of the printout after program DIG1 has been run, example

```

OLD TP2FIL
*LIST

10$R,J
20$:IDENT:USERID,USERNAME
30$:UTILITY
40$:FUTIL:F3,F2,COPY/1R/,HOLD/F2/
50$:FUTIL:F1,F2,COPY/1F/,RWD/F2/
60$:TAPE9:F1,X1D,,BCD TAPENO,,BCDTAPE NAME
70$:FILE:F2,X2S,1L
80$:DATA:F3,,COPY
90:INPUT,ASIS
100$:ENDCOPY
110$:PROGRAM:TS CONV
120$:FILE:I*,X2R
130$:FILE:QT,,1L,NEW,PF NAME
140$:ENDJOB

```

\*  
Figure 19. Program TP2FIL to save BCD tape as a permanent file

shown in Figure 20. The same BCD TAPE NAME should be used as that previously used in DIG1.)

- h. Type in  
PS:/130/  
The system will respond with  
130\$:FILE:OT,1L,NEW,PF NAME
- i. Replace the PF NAME with actual permanent file name  
Type in  
RVS:/PF NAME/;/ACTUAL PF NAME  
(The same PF NAME as BCD TAPE NAME is suggested.)
- j. Type in  
RESAVE TP2FIL
- k. Type in  
DONE
- l. Type in  
RUN  
The system will respond with  
SNUMB XXXXXT

OPERATOR STARTED WITH #10048 FOR FILE CODE 03 GE 400 BYL GE PHX 10048 10048 0001 84016 000MARTIN8CD  
T4UMD2 10048 WAS CHAINED TO CONTROL MASTER TAPENAME ROCRMSC  
\* NORMAL TERMINATION AT 021343 1=5000 SW=0000000000000

START	9.294	LINES	213	PROC	0.0018	I/O	0.001	IU	5	MEMORY	15K
STOP	9.299	LIMIT	20480	LIMIT	0.3000	LIMIT		CU	5	M-T	343
SWAP	0.000										
LAPSE	0.005	FC D	TYPE	BUSY	IP/AT	FP/RT	IS/RC	MS/RE	ADDRESS	TR/PK#	
		9* R	NSU500 *	42	4	4	36	36	0-12-20		
		R* R	NSU500 *	11	0	0	1	1	0-12-13		
		01 D	TAPE-9	1326		0/01	406	0	0-16-05	#U0180	
		03 D	TAPE-9	352		0/03	49	0	0-18-05	#10048	
		P*	SYOUT								
		L* R	NSU450 *	1290	0	0	1200	1200R	0-08-02	-	
		*L R	NSU500 *	60	0	0	500	500R	0-12-13		

LIST 99 LINES  
RC-52 114 LINES

#### ACTIVITY COST SUMMARY

RESOURCE DESCRIPTION	RESOURCE USAGE	BILLING UNITS
PROCESSOR (SECS)	6	10
DISC I/O TIME (SECS)	1	1
TAPE I/O TIME (SECS)	2	1

Figure 20. Example showing how BCD TAPE NUMBER is obtained from log file of printout after program DIG1 is run

39. Digitizing errors may be edited from the tape with the following procedures.

- a. Sign on the DPS1 computer at WES
- b. Type in  
OLD PFNAME  
(PFNAME is the permanent file name used in TP2FIL.)

- c. Type in  
EDIT  
The system will respond with a "-" to indicate that it is in the EDIT mode.
- d. Use the editor command to correct all errors.
- e. Type in  
DONE  
The system will respond with a "\*" and return to the CARDIN mode waiting for the next command.
- f. Type in  
RESAVE PFNAME  
(This should be the same file name as PFNAME.)

40. Program CONVER will convert the digitized values of the x and y coordinates to prototype units (Figure 21).

- a. Sign on the DPS1 computer at WES
- b. Type in  
OLD ROHH314/CONVER,R  
CLEAR  
SAVE CONVER
- c. Type in  
EDIT
- d. Replace USERID and USER NAME by actual user's ID and NAME  
Type in  
RVS:/USERID,USERNAME/;/ACTUAL USER'S ID, ACTUAL USER'S NAME/
- e. Type in  
PS:/PARAMETER/  
The system will respond with the statement  
150 PARAMETER XMO=0,YMO=0,XM1=12., YM1=0.  
(where XMO, YMO, XM1, and YM1 are coordinates of reference points in the prototype units)
- f. Type in  
RVS:/XMO=OLD VALUE,YMO=OLD VALUE/;/XMO=NEW VALUE,YMO=NEW VALUE/  
RVS:/XM1=OLD VALUE,YM1=OLD VALUE/;/XMO=NEW VALUE,YM1=NEW VALUE/
- g. Locate and replace with parameter N1 and N2 in Line 160  
Type in  
PS:/160/  
RVS:/N1=OLD VALUE,N2=OLD VALUE/;/N1=NEW VALUE,N2=NEW VALUE/
- h. Locate and change the format statement in Line 290  
Type in  
PS:/290/  
RVS:/FORMAT(4(i6,2F7.2))/;/THE DESIRED FORMAT/

```

      OLD CONVER
      *LIST

100:IN
110:IDENT:USERID,USERNAME
120:OPTION:FORTRAN
130:USE:GTLIT
140:FORM:NFORN,NLNO
150 PARAMETER XMO=0.,YMO=0.,XM1=12.,YM1=0.
160 PARAMETER N1=1851,N2=3973
170 PARAMETER N3=N2-N1+1
180 DIMENSION XP(N3),YP(N3),NTT(N3)
190 DIST=SQRT((ABS(XM1-XMO))**2+(ABS(YM1-YMO))**2.)
200 DO 255 I=1,N3
210 NTT(I)=I+N1-1
220 255 CONTINUE
230 READ(1,100) X0,Y0
240 READ(1,100) X1,Y1
250 100 FORMAT(2X,F4.0,2X,F4.0)
260 READ(1,100)(XP(I),YP(I),I=1,N3)
270 CALL CONVER(X0,Y0,X1,Y1,N1,N2,XP,YP,DIST,XMO,YMO)
280 WRITE(43,200) (NTT(I),XP(I),YP(I),I=1,N3)
290 PRINT 200,(NTT(I),XP(I),YP(I),I=1,N3)
300 200 FORMAT(4(I6,2F7.2))
310 REWIND 1
320 CALL DETACH(1,,)
330 STOP
340 END
350 SUBROUTINE CONVER(X0,Y0,X1,Y1,N1,N2,X,Y,DIST,XMO,YMO)
360 DIMENSION X(1),Y(1)
370 HYP=SQRT((Y1-Y0)**2+(X1-X0)**2)
380 SCALE=DIST/HYP
390 SINE=((Y1-Y0)*SCALE)/DIST
400 COSINE=((X1-X0)*SCALE)/DIST
410 N3=N2-N1+1
420 DO 10 I=1,N3
430 XX=((X(I)-X0)*COSINE+(Y(I)-Y0)*SINE)*SCALE+XMO
440 Y(I)=(-(X(I)-X0)*SINE+(Y(I)-Y0)*COSINE)*SCALE+YMO
450 X(I)=XX
460 10 CONTINUE
470 RETURN
480 END
490:EXECUTE
500:LIMITS:02,16K,,3000
510:PRMFL:01,R,L,USERID/PF NAME
520:ENDJOB

```

Figure 21. Program CONVER to convert digitized values of x and y coordinates to prototype values

- i. Locate and replace the parameter of USERID and PFNAME in Line 490  
 Type in  
 PS:/490/  
 RVS:/USERID/:/ACTUAL USER'S ID/  
 RVS:/PFNAME/:/  
 (Same file name that was used in Line 130 in file TP2FIL.)
- j. Type in  
 RUN  
 The system will respond with  
 SNUMB XXXXXT

## Plotting the Finite Element Grid

41. After the finite element grid data have been prepared according to the above procedures, the grid may be plotted by use of the WES Graphics Compatibility System (GCS) (1979) subroutines. The plot file can be directed either to a Calcomp plotter or to a Tektronix 4014 terminal interactively. This program FNGRID listing is presented in Figure 22.

### Steps to run FNGRID

42. Program FNGRID may be run by using the following procedures.

- A. Use the XEDIT mode editor to change the total number of nodal points and elements of the grid.
  - a. Sign on CYBERNET (Control Data Corporation) COMPUTER SYSTEM  
Telephone No. 2047 for 300 Baud  
Telephone No. 2030 for 1200 Baud
  - b. Call out the procedure file PLOTF  
Type in  
GET,PLOT/UN=CEROMO  
SAVE, PLOTF
  - c. Use XEDIT to make necessary changes  
Type in  
XEDIT
  - d. Type in  
L/IXY/  
The system will respond with  
Q,FNGRID.C/IXY/35/\*;C/NEL/48/\*
  - e. Change the total number of nodes (IXY) and elements (NEL)  
to the desired number  
Type in  
C/35/TOTAL NO. OF NODES/  
C/48/TOTAL NO. OF ELEMENTS/
  - f. Option: If the user does not wish to change data file  
names FINDAT and FINDAT1 to other names, go to  
section g. Otherwise,  
Type in  
C/FINDAT/NEW FILE NAME/  
C/FINDAT1/NEW FILE NAME/
  - g. Type in  
E,,RL  
(This command will terminate the editing mode and the  
file PLOTF will be replaced by the edited version.)

```

OLD,FNGRID
/LIST      PROGRAM GRIDFL(INPUT,OUTPUT,TAPES=INPUT,TAPE6,TAPE8,
          *TAPE12,TAPE13,TAPE10,TAPE66,TAPE77,TAPE9,TAPE99)
C *** IXY IS THE MAX NUMBER OF NODES
C *** NEL IS THE MAX NUMBER OF ELEMENTS
C *** N1-N4 IS THE NODE NUMBER OF EACH ELEMENT
C *** DEP IS THE DEPTH AT EACH NODE
C *** IC1=0 PLOT NODE AND ELEMENT NUMBERS
C *** IC1=1 PLOT ELEMENTS NUMBERS.
C *** IC1=2 NO NUMBERS PLOTTED
C *** IC2=0 NO DEPTH DATA OR PLOT
C *** IC2=1 READ AND PLOT DEPTH DATA
C *** XTR,YTR=X AND Y COORDINATES OF THE CENTER OF THE SEMICIRCLE.
C *** ANGG=ANGLE IN RADIANS OF SEMICIRCLE DIAMETER FROM GRID X-AXIS.
C *** RR=RADIUS OF SEMICIRCLE IN FEET
C *** NDEV=0 PLOT FILE IS DIRECTED TO THE CALCOMP PLOTTER.
C *** NDEV=1 PLOT FILE IS DIRECTED TO THE TEKTRONIX 4014 TERMINAL.
C *** NODR=NO. OF POINTS ON THE CIRCUMFERENCE OF THE SEMICIRCLE (OR CIRCLE).
C *** NCL=1 SEMICIRCLE GRID IS USED.
C *** NCL=0 FULL CIRCLE GRID IS USED.
C *** FACT IS THE FACTOR USED TO INCREASE OR DECREASE THE ORIGINAL PLOT SIZE.
C *** FACT=1.0 IF NDEV=1
C *** WXMAY= THE RIGHT-MOST WINDOW BOUNDARY. (SEE GCS MANUAL)
C *** WXMIN= THE LEFT-MOST WINDOW BOUNDARY. (SEE GCS MANUAL)
C *** WYMAX= THE TOP-MOST WINDOW BOUNDARY. (SEE GCS MANUAL)
C *** WYMIN= THE BOTTOM-MOST WINDOW BOUNDARY. (SEE GCS MANUAL)
C *** XLO= THE X COORDINATE OF THE LOWER LEFT CORNER OF THE
C          FIRST CHARACTER OF THE OUTPUT. (SEE GCS MANUAL)
C *** YLO= THE Y COORDINATE OF THE LOWER LEFT CORNER OF THE
C          FIRST CHARACTER OF THE OUTPUT. (SEE GCS MANUAL)
C *** RTITLE= TITLE OF THE PLOT
C *** NAME1= IDENTIFIER USED FOR THE PROJECT
C *** USE PROC. FILE 'PLOT.F' TO SET DESIRED DIMENSIONS.
C
COMMON LDUM(2000)
DIMENSION X(IXY),Y(IXY),DEP(IXY)
DIMENSION K(NEL),N1(NEL),N2(NEL),N3(NEL),N4(NEL)
DIMENSION XAVE(NEL),YAVE(NEL)
DIMENSION NAME1(10)
DIMENSION RTITLE(8)
READ(12,10) NDEV,NODR,NCL,FACT
10 FORMAT(3I5,F5.1)
IR1='R1'
IV1=0
IV2=1
CALL SETJCI(IR1,IV1)
IF(NDEV.EQ.1) CALL SETJCI(IR1,IV2)
READ(12,15) NAME1
15 FORMAT(10A6)
NSPACE=NODR-1
READ(12,20) SCALE,IC1,IC2
20 FORMAT(F10.2,2I10)
READ(12,40) XTR,YTR,ANGG,RR
40 FORMAT(4F10.2)
READ(13,50) (X(I),Y(I),I=1,IXY)
50 FORMAT(3(6X,2F9.3))
PAI=3.1416
IF(NCL.EQ.1) DA2=PAI/NSPACE
IF(NCL.EQ.0) DA2=2.*PAI/NODR
NNOD=IXY
NODR2=NNOD-NODR

```

Figure 22. Program FNGRID for plotting the finite element solution  
(Sheet 1 of 3)



```

      WRITE(8,95)
      WRITE(8,105) NAME1
      WRITE(8,96)
      95 FORMAT(//,10X'*****')
      105 FORMAT(//,20X,10A6,/)
      96 FORMAT(10X,'*****')
C *** K(I) USE TEMPORARY
      DO 60 I=1,IXY
      60 K(I)=I
      READ(9,70) (DEF(I),I=1,NNOD)
      70 FORMAT(16F5.2)
      WRITE(8,115)
      115 FORMAT(7X,'NODE',11X,'X-COORD',11X,'Y-COORD',11X,'DEPTH')
      WRITE(8,90) (K(I),X(I),Y(I),DEF(I),I=1,IXY)
      90 FORMAT(110,2X,F15.2,2X,F15.2,2X,F15.2)
      NODR1=IXY-NODR+1
      N=IXY
      M=NEL
      DO 130 I=1,N
      X(I)=X(I)*SCALE
      Y(I)=Y(I)*SCALE
      130 CONTINUE
C *** PRINT INTERMEDIATE DATA
      140 FORMAT(1X,12A6)
      WRITE(8,150) N,M,YR,SCALE
      150 FORMAT(1X,12HNO OF POINTS,15,/,1X,14HNO OF ELEMENTS,15,/,1X,16HRAN
      *GE OF Y-COORD,F10.0,/,1X,22HSCALE FACTOR (IN/FEET),E10.3)
C *** CALCULATE ELEMENT CENTROIDS
      WRITE(8,160)
      160 FORMAT(//,7HELEMENT,1X,4HR(1),2X,4HR(2),2X,4HR(3),2X,7HELEMENT,1X,
      *4HR(1),2X,4HR(2),2X,4HR(3),2X,7HELEMENT,1X,4HR(1),2X,4HR(2),2X,4HR
      *(3))
      READ(9,170) (N1(I),N2(I),N3(I),I=1,NEL)
      170 FORMAT(3(5X,3I5))
      180 FORMAT(4I6,2X,4I6,2X,4I6)
      WRITE(8,130) (I,N1(I),N2(I),N3(I),I=1,NEL)
      WRITE(10,250) (X(I),I=1,IXY)
      WRITE(10,250) (Y(I),I=1,IXY)
      WRITE(10,170) (N1(I),N2(I),N3(I),I=1,NEL)
      WRITE(10,250) (DEF(I),I=1,NNOD)
      250 FORMAT(8F10.2)
C *** READ IN DATA FOR X-RANGE AND Y-RANGE ***
      READ(12,251) WXMAX,WXMIN,WYMAX,WYMIN
      251 FORMAT(4F10.1)
C *** READ IN DATA TO LABEL THE PLOT ***
      READ(12,41) XLO,YLO
      41 FORMAT(2F6.2)
      READ(12,42) RTITLE
      WRITE(8,42) RTITLE
      42 FORMAT(8A10)
      DO 35 I=1,M
      35 N4(I)=0
      IF (IC1.GE.2) GO TO 220
      DO 200 I=1,M
      NN1=N1(I)
      NN2=N2(I)
      NN3=N3(I)
      NN4=N4(I)
      XAVE(I)=X(NN1)+X(NN2)+X(NN3)
      YAVE(I)=Y(NN1)+Y(NN2)+Y(NN3)
      IF (N4(I).GT.0) GO TO 210
      XAVE(I)=XAVE(I)/3.
      YAVE(I)=YAVE(I)/3.
      GO TO 200
      210 XAVE(I)=(XAVE(I)+X(NN4))/4.
      YAVE(I)=(YAVE(I)+Y(NN4))/4.

```

Figure 22. (Sheet 2 of 3)

```

200 CONTINUE
220 CALL USTART
    CALL USET('SPEED',120.)
    CALL UERASE
    CALL URELL
C    CALL USET('TERMINATOR',';')
    IF(NDEV.EQ.1) GO TO 225
    CALL USET('ALTE')
    CALL UERASE
225 CONTINUE
    CALL USET('DEVICE')
    CALL FACTOR(FACT)
    CALL UDAREA(0.0,14.0,0.5,10.)
    CALL USET('VIRTUAL')
    CALL UWINDO(WXMAX,WXMIN,WYMAX,WYMIN)
    DO 25 I=1,M
        XI=I
C *** MOVE PEN TO FIRST ELEMENT NODE
        M1=M1(I)
        M2=M2(I)
        M3=M3(I)
        M4=M4(I)
        CALL USET('NOAXES')
        CALL USET('LINE')
        CALL UMOVE(X(M1),Y(M1))
        CALL UPEN(X(M2),Y(M2))
        CALL UMOVE(X(M2),Y(M2))
        CALL UPEN(X(M3),Y(M3))
        CALL UMOVE(X(M3),Y(M3))
        IF(M4.EQ.0) GO TO 26
        CALL UPEN(X(M4),Y(M4))
        CALL UMOVE(X(M4),Y(M4))
26    CALL UPEN(X(M1),Y(M1))
25    CONTINUE
        IF(IC1.EQ.2) GO TO 27
        DO 275 I=1,M
            ELE=I
            CALL UMOVE(XAVE(I),YAVE(I))
            CALL USET('SHALL')
            CALL USET('INTEGER')
            CALL UPRINT(XAVE(I),YAVE(I),ELE)
275    CONTINUE
            IF (IC1.GE.1) GO TO 27
            DO 270 I=1,N
                EN=I
                CALL UMOVE(X(I),Y(I))
                CALL USET('SHALL')
                CALL USET('INTEGER')
                CALL UPRINT(X(I),Y(I),EN)
270    CONTINUE
27    CONTINUE
        IF (IC2.EQ.0) GO TO 116
        CALL USET('HARDWARE')
        CALL USET('SHALL')
        DO 117 I=1,NNOD
            CALL USET('REAL')
            CALL UPRINT(X(I),Y(I),DEF(I))
117    CONTINUE
116    CONTINUE
C *** LABEL PLOT ***
        CALL USET('VIRTUAL')
        CALL USET('LARGE')
        CALL USET('TEXT')
        CALL UPRINT(XLO,YLO,RTITLE)
        CALL UEND
        WRITE(3,1000)
1000    FORMAT(1X,'PLOTTING COMPLETE')
        STOP
        END

```

Figure 22. (Sheet 3 of 3)

B. Use procedure file to run program FNGRID.

- a. Type in  
OLD,PLOTF  
BEGIN,RUNPL,PLOTF  
The system will respond by printing out the statements  
which are edited by "Q" statement in file PLOTF
- b. Answer the first question of PROGRAM FILE NAME  
Type in  
FNGRID1
- c. Answer the question of TYPES (X,N,B) OF FILE  
Type in  
S
- d. Answer the question of DEVICE  
Type in  
DR4 (if Calcomp plotter is chosen)  
TK4 (if Tektronix 4014 terminal is chosen)  
(Note: Computer will begin to plot on the screen if  
TK4 is chosen; computer will respond with more ques-  
tions if DR4 is chosen.)
- e. Answer the question of USER'S ID  
Type in  
CEROXX (the user's ID)  
The system will respond with  
TAPE 99 ROUTED THRU AJZZ123  
(where AJZZ123 is the job name of the plot file)
- f. Call (Ext 3442) the operator of the COPE terminal at the  
WES Automatic Data Processing (ADP) Center to retrieve the  
plot file. (Note: TAPE10 is saved and replaced by file  
name FINDAT after the run, and will be used as data file to  
run program FINITE.)

Data preparation information

43. The variable names and format allocations for program FNGRID are as follows.

DATA SET NO. 1

CARD NO. 1

<u>Col.</u>	<u>Format</u>	<u>Variable Name</u>	<u>Description</u>
1 - 5	I5	NDEV	NDEV=0, plot file is directed to the Calcomp plotter NDEV=1, plot file is directed to the Tek- tronix 4014 terminal
6 - 10	I5	NODR	Number of points on circumference
11 - 15	I5	NCL	NCL=0, full circle grid is used NCL=1, semicircle grid is used

<u>Col.</u>	<u>Format</u>	<u>Variable Name</u>	<u>Description</u>
16 - 20	F5.1	FACT	Factor used to change original plot size. (Note: If NDEV=1, then FACT=1.0.)
<u>CARD NO. 2</u>			
1 - 60	10A6	NAME1	Identifier used for the project
<u>CARD NO. 3</u>			
1 - 10	F10.2	SCALE	SCALE=1 and 2, x and y coordinates of the nodes are in feet and inches, respectively
11 - 20	I10	IC1	IC1=0, plot node numbers and element numbers IC1=1, plot element numbers only IC1=2, no number plotted
21 - 30	I10	IC2	IC2=0, no depth data on plot IC2=1, read and plot depth data
<u>CARD NO. 4</u>			
1 - 10	F10.2	XTR	X - coordinate of the center of semicircle
11 - 20	F10.2	YTR	Y - coordinate of the center of semicircle
21 - 30	F10.2	ANGG	Angle of the semicircle (radians)
31 - 40	F10.2	RR	Radius of the semicircle (feet)
<u>CARD NO. 5</u>			
1 - 10	F10.1	WXMAX	The rightmost window boundary (See GCS 1979 manual)
11 - 20	F10.1	WXMIN	The leftmost window boundary (See GCS 1979 manual)
21 - 30	F10.1	WYMAX	The topmost window boundary (See GCS 1979 manual)
31 - 40	F10.1	WYMIN	The bottommost window boundary (See GCS 1979 manual)
<u>CARD NO. 6</u>			
1 - 6	F6.2	XLO	x-coordinate of the lower left corner of the first character of the output (See GCS 1979 manual)
7 - 12	F6.2	YLO	y-coordinate of the lower left corner of the first character of the output (See GCS 1979 manual)

Col.	Format	Variable Name	Description
------	--------	---------------	-------------

CARD NO. 7

1 - 80	8A10	RTITLE	Title of plot
--------	------	--------	---------------

DATA SET NO. 2

CARD NO. 1

(Note: This data set is obtained after the program CONVER is run.)

1 - 6	Blanks		
7 - 14	F8.3	X(1)	x-coordinate of node 1
15 - 22	F8.3	Y(1)	y-coordinate of node 1
23 - 28	Blanks		
29 - 36	F8.3	X(2)	x-coordinate of node 2
37 - 44	F8.3	Y(2)	y-coordinate of node 2
45 - 50	Blanks		
51 - 58	F8.3	X(3)	x-coordinate of node 3
59 - 66	F8.3	Y(3)	y-coordinate of node 3

(Note: Six values on each card. Total number of x and y values should equal the total number of nodes.)

DATA SET NO. 3

CARD NO. 1

1 - 5	F5.1	DEP(1)	Depth in feet at each nodal point
6 - 10	F5.1	DEP(2)	(Note: Sixteen values on each card, and use as many cards as necessary.)
.			
.			
.			
.			
76 - 80	F5.1	DEP(16)	

DATA SET NO. 4

CARD NO. 1

1 - 5	I5	K(1)	Dummy variable used as an index number for the element
6 - 10	I5	N1(1)	First nodal point of element 1
11 - 15	I5	N2(1)	Second nodal point of element 1
16 - 20	I5	N3(1)	Third nodal point of element 1

Col.	Format	Variable Name	Description
21 - 25	I5	K(2)	Dummy variable
26 - 30	I5	N1(2)	First nodal point of element 2
31 - 35	I5	N2(2)	Second nodal point of element 2
36 - 40	I5	N3(2)	Third nodal point of element 2
41 - 45	I5	E(3)	Dummy variable
46 - 50	I5	N1(3)	First nodal point of element 3
51 - 55	I5	N2(3)	Second nodal point of element 3
56 - 60	I5	N3(3)	Third nodal point of element 3

(Note: Twelve values on each card for as many cards as needed. The order of N1, N2, and N3 of each element is chosen by following a counterclockwise direction.)

#### Example run

44. The finite element grid of Figure 17 will be processed as a typical representative example of the capability of the programs.

- A. Use XEDIT mode to set the total number of nodes to 35 and total number of elements to 48 (Figure 23).

```

      GET,PLOTF/UN=CEROM0
      /SAVE,PLOTF
      /OLD,PLOTF
      /XEDIT
      XEDIT 3.1.00
      ?? L/Q,FNGRID/
      Q,FNGRID.C/IXY/30/*;C/NEL/40/*
      ?? C/30/35/
      Q,FNGRID.C/IXY/35/*;C/NEL/40/*
      ?? C/40/48/
      Q,FNGRID.C/IXY/35/*;C/NEL/48/*
      ?? E,,RL
      PLOTF  REPLACED
      PLOTF  IS A LOCAL FILE
      AEB ,   0.254UNTS.
      /

```

Figure 23. Using XEDIT mode to set total number of nodes and elements

- B. Run program FNGRID

- a. Plot file is directed to the Tektronix 4014 terminal (Figure 24).

```

OLD,PLOTF
/BEGIN,RUNPL,PLOTF,FD1,FD2,FD3.
C *** 35 IS THE MAX NUMBER OF NODES
  DIMENSION X(35),Y(35),DEP(35)
  READ(13,50) (X(I),Y(I),I=1,35)
  NNOD=35
  DO 60 I=1,35
    WRITE(8,90) (K(I),X(I),Y(I),DEP(I),I=1,35)
    NODB1=35-NODR+1
    N=35
    WRITE(10,250)(X(I),I=1,35)
    WRITE(10,250)(Y(I),I=1,35)
  END OF FILE
C *** 48 IS THE MAX NUMBER OF ELEMENTS
  DIMENSION K(48),N1(48),N2(48),N3(48),N4(48)
  DIMENSION XAUE(48),YAUE(48)
  N=48
  READ(9,170) (N1(I),N2(I),N3(I),I=1,48)
  WRITE(8,180)(I,N1(I),N2(I),N3(I),I=1,48)
  WRITE(10,170)(N1(I),N2(I),N3(I),I=1,48)
END OF FILE
ENTER PROGRAM FILENAME
? FNGRID1
ENTER S FOR SOURCE FILE WITH NO LINE NUMBERS
ENTER M FOR SOURCE FILE WITH LINE NUMBERS
ENTER B FOR BINARY FILE
? S
DEVICE-
? TK4

```

Figure 24. Directing plot file to  
Tektronix 4014 terminal

b. Plot file is directed to the Calcomp plotter (Figure 25).

```

OLD,PLOTF
/BEGIN,RUNPL,PLOTF,FD1,FD2,FD3.
C *** 35 IS THE MAX NUMBER OF NODES
  DIMENSION X(35),Y(35),DEP(35)
  READ(13,50) (X(I),Y(I),I=1,35)
  NNOD=35
  DO 60 I=1,35
    WRITE(8,90) (K(I),X(I),Y(I),DEP(I),I=1,35)
    NODB1=35-NODR+1
    N=35
    WRITE(10,250)(X(I),I=1,35)
    WRITE(10,250)(Y(I),I=1,35)
  END OF FILE
C *** 48 IS THE MAX NUMBER OF ELEMENTS
  DIMENSION K(48),N1(48),N2(48),N3(48),N4(48)
  DIMENSION XAUE(48),YAUE(48)
  N=48
  READ(9,170) (N1(I),N2(I),N3(I),I=1,48)
  WRITE(8,180)(I,N1(I),N2(I),N3(I),I=1,48)
  WRITE(10,170)(N1(I),N2(I),N3(I),I=1,48)
END OF FILE
ENTER PROGRAM FILENAME
? FNGRID1
ENTER S FOR SOURCE FILE WITH NO LINE NUMBERS
ENTER M FOR SOURCE FILE WITH LINE NUMBERS
ENTER B FOR BINARY FILE
? S
DEVICE-
? DR4
ENTER YOUR USER NUMBER
? CER0MB
TAPE99 ROUTED THRU JOB AJZZ324
CALL DOT GRIFFIN (TEL.3442) & SPECIFY 3-BIT SOFTWARE
REVERT.
/

```

Figure 25. Directing plot file to Calcomp  
plotter terminal

C. Listing of data files (FD1, FD2, FD3) (Figure 26).

```

OLD,FD1
/LIST
      0      9      1      1.0
SAMPLE PROBLEM
      1.00      0      0
      0.00      0.00      0.00      9.00
      -35.0      35.0      -40.0      15.0
      -8.00-37.00
FINITE ELEMENT GRID\

```

Figure 26a. Listing of data file FD1

```

OLD,FD2
/LIST
-8.000 -32.000      0.000 -32.000      8.000 -32.000
-4.000 -28.000      4.000 -28.000      -8.000 -24.000
 0.000 -24.000      8.000 -24.000      -4.000 -20.000
 4.000 -20.000      -8.000 -16.000      0.000 -16.000
 8.000 -16.000      -4.000 -12.000      4.000 -12.000
-8.000 -8.000      0.000 -8.000      8.000 -8.000
-4.000 -4.000      4.000 -4.000      -8.000  0.000
 0.000  0.000      8.000  0.000      -4.000  4.000
 4.000  4.000      0.000  8.000      12.000  0.000
11.000  4.600      8.500  8.500      4.600 11.100
 0.000 12.000      -4.600 11.100      -8.500  8.500
-11.100  4.600      -12.000  0.000

```

Figure 26b. Listing of data file FD2

```

OLD,FD3
/LIST
0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25
0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25
0.25 0.25 0.25
 1  2  4      2  3  5      1  4  6
 4  7  6      2  7  4      2  5  7
 5  8  7      3  8  5      6  7  9
 7  8 10      6  9 11      9 12 11
 7 12  9      7 10 12      10 13 12
 8 13 10      11 12 14      12 13 15
11 14 16      14 17 16      12 17 14
12 15 17      15 18 17      13 18 15
16 17 19      17 18 20      16 19 21
19 22 21      17 22 19      17 20 22
20 23 22      18 23 20      35 21 34
21 22 24      22 23 25      23 27 28
21 24 34      22 25 24      23 28 25
34 24 33      24 25 26      25 28 29
24 32 33      24 26 32      25 30 26
25 29 30      26 31 32      26 30 31

```

Figure 26c. Listing of data file FD3



The computer plot of the finite element grid originally conceived in Figure 17 is presented in Figure 27 after processing by the programs DIG1, TP2FIL, CONVER, and FNGRID.

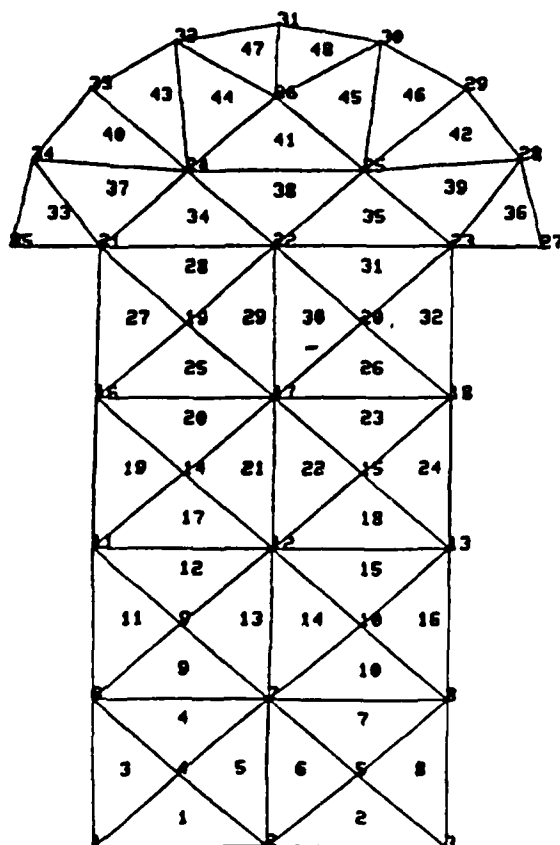


Figure 27. Computer plot of finite element grid

#### PART IV: PROGRAM FINITE

45. The propagation of periodic, small amplitude surface gravity waves over a variable depth seabed of mild slope is governed by

$$A'' (cc_g Ad) + \frac{c}{c} l^2 d = 0 \quad (1 \text{ bis})$$

Equation 1 is solved numerically by program FINITE using a hybrid finite element method originally developed by Chen and Mei (1974) to solve the diffraction Helmholtz equation in a constant depth region.

#### Data Preparation for Program FINITE

46. Two types of data are necessary to run program FINITE: (a) data values defined by parameter statements in the program FINITE and (b) data submitted to the program FINITE by data files. Program FINITE is presented in Figure 28.

#### Data values defined by parameter statements

47. The following data values are defined by parameter statements in the program FINITE.

<u>Variable Name</u>	<u>Format</u>	<u>Description</u>
NNOD	Integer	Total number of nodes
NELE	Integer	Total number of elements
NODE	Integer	Total number of radiation boundary nodal points
NCS*	Integer	Total number of coefficients in the expansion of radiation domain
ISPT	Integer	Number of selected elevation station (nodes)
ISPTE	Integer	Number of selected elevation station (elements)
NSYSK	Integer	NLGL x NBAND x 2 + 50 (see comment statements in program FINITE)
NSYTP	Integer	NLGL x NBAND + 100 (see comment statements in program FINITE)

(\*Note: The value of NCS is not known a priori. Enough terms must be included such that additional terms have a negligible effect on the solution. NCS can be estimated by determining the argument ( $2\frac{1}{2}R/L$ ) of the J Bessel Functions

(Committee for the Calculation of Mathematical Tables 1958). The values of different order J Bessel Functions with this argument can be determined using Bessel Function tables. When the value of a Bessel Function of higher order becomes much less than the lower order Bessel Function of the same argument, NCS is set equal to the order of the higher order Bessel Function. For  $h = 1$  ,  $k = 12$  ,  $T = 2$  sec;  $l = (\sqrt{gh})T = 11.4$  ft,  $(2\pi R/L) = 6.64$  . Since  $J_{13}(6.64)$  is much less than  $J_0(6.64)$  , NCS is set equal to 13. The model should then be run with NCS equal to both 13 and 14. If the results are the same within desired tolerances, the value of NCS = 13 is confirmed.)

Data values submitted by data files

48. Data file FINDAT1 contains Data Set No. 1 through Data Set No. 3. Data file FINDAT contains Data Set No. 4 through Data Set No. 7. (FINDAT can be obtained after running the plotting program FNGRID.)

```

OLD,FINITE
/LIST
*DECK MAIN
  PROGRAM LALB (INPUT,OUTPUT,TAPES=INPUT,TAPE6=OUTPUT,TAPE4,
1TAPE9,TAPE11,TAPE12,TAPE13,TAPE14,TAPE15,TAPE16,TAPE17,TAPE18,
1TAPE19,TAPE20,TAPE21,TAPE22,TAPE23,TAPE24,TAPE25)
C
CCC BARBERS POINT HARBOR OSCILLATION STUDY
C
C *****
C NELE= TOTAL NO. OF ELEMENTS
C NNOD= TOTAL NO. OF NODES
C NODR=TOTAL NO.OF RADIATION-BOUNDARY NODAL POINTS
C NCS =TOTAL NO.OF COEFF. IN THE EXPANSION OF RADIATION DOMAIN
C NEQT= TOTAL NO. OF SIM. LIN. EQS. =NNOD+NODR
C*****
  COMPLEX SYSQ,YSQ,XH,DH,SM
  *,SYTP,STMP,FTEHP
  COMMON/DB/ WK,ALPHA,D1,DA2,DA4,RR,WR,XL,WL,RKHP,HKL
  DIMENSION X(1277),Y(1277),NOD(1277),RCON(2334,3),XJ(25),
1 XY(25),XH(25),DH(25),ANGL(13),SH(13),DD(2334),HSP(100),IPER(5)
  DIMENSION AF(1297),AT(1297),ID(20),HSPE(100)
  DIMENSION U(2334),V(2334),YC(2334),Z(3)
  COMMON/L1/SYSK(19850)
  COMMON/L2/SYSQ(1300)
  COMMON/L3/STMP(1300)
  COMMON/L4/SYTP(9950)
  DIMENSION FTEMP(9950)
  DIMENSION VJ(105),VY(105)
  DIMENSION NR(3)
  DIMENSION XK(25)
  COMMON /NEW/ NUMBLK,NLG,NLGL,L11,LS
1 ,L4,L3
  LEVEL 2,SYSK,YSQ,STMP,SYTP,FTEMP
  EQUIVALENCE (FTEMP(1),SYTP(1))
  DATA (IPER(J),J=1,5)/4HWAVE,4H PER,4HIOD ,4HIN S,4HECS=/
  IPC = 0
  IFMAX = 0
  READ(5,2) ID
2 FORMAT(20A4)
  WRITE(6,3) ID
3 FORMAT(//,35X,20A4,////)
  READ(5,5430)NBARD,NNOD,NELE,NODR,NCS,IPR,RR,ALPHA,DM,IBLKLEN
5430 FORMAT(6I5,F10.2,F10.5,F10.2,1T6)
  NELE3=3*NELE
  NEQT=NNOD+NCS
  NODR1=NODR-1
  NUMBLK = NEQT*NBARD/IBLKLEN + 1
  PAI = 3.141592654
  D1 = 1.0
  DA2 = PAI/NODR1
  DA4 = DA2/2.
5431 NLG=NEQT/NUMBLK
  NLGL=NEQT-(NUMBLK-1)*NLG
  NLGG=2*NLGL
  IF (NLGG*NBARD.LT.19850)GO TO 5432
  NUMBLK = NUMBLK + 1
  GO TO 5431
5432 CONTINUE
  WRITE(6,12)NELE,NNOD,NODR,NCS,NEQT,ALPHA,DA2,DA4,RR,D1,DM
12 FORMAT(/1X,23HTOTAL NO. OF ELEMENTS =,15,3X,20HTOTAL NO. OF NODES
1=,15,3X,23HTOTAL NO. OF SOURCES =,15,3X,30HFIRST ELEMENT W.R.T. SO
2URCES =,15,1X,30HTOTAL NO. OF SIM. LINEAR EQS =,15,1X,25HWAVE ANG

```

Figure 28. Program FINITE for solving hybrid finite element model  
(Sheet 1 of 23)

3LE OF INCIDENCE =,F10.5,4X,29HINCREMENT IN ANG DIRECTION = 2F10.4  
 4,1X,32HOUTEST EXTEND OF FINITE DOMAIN =,F10.2,24X,29HNDOKM, DEPTH 0  
 5F OUTER REGION =,F5.2,5X,31HAYER, DEPTH(FT) OF SPHICICACLE =,F10.2,  
 6//)

```

C*****
C   WK = WAVE NO.
C   ALPHA = WAVE ANGLE OF INCIDENCE
C   D1 = WATER DEPTH OF OUTER REGION
C   D2 = INCREMENT IN ANGULAR DIRECTION
C*****
IF (IFR.NE. 1) GO TO 2013
PRINT 2010
2010 FORMAT(50X,2BHINUT DATA CHECK--ECHO PRINT
PRINT 2014) NUNBLA,NLGL,NLGL,IBLALN,IPR,NUNBL
2014 FORMAT(//,1X,6I6)
2013 CONTINUE
READ(5,300)THAX,THIN,TDELT,INK
IF(IPR.EQ.0)GO TO 3020
PRINT 300,THAX,THIN,TDELT,INK
300 FORMAT(3F10.2,I3)
3020 XK(1) = THIN
DO 320 J = 2,INK
J1 = J - 1
XK(J) = XK(J1) + TDELT
320 CONTINUE
READ(5,305)IPC,IPMAX,ISPT,IDPC,ISFTE,IDCH,IBUGA,IBUGG,IBUGL
305 FORMAT(9I5)
IF(IPR.EQ.0)GO TO 3010
PRINT 305,IPC,IPMAX,ISPT,IDPC,ISFTE,IDCH,IBUGA,IBUGG,IBUGL
3010 IF(IPC.EQ.0)GO TO 3000
READ(5,306)(NSP(J),J=1,ISPT)
READ(5,306)(NSPE(J),J=1,ISFTE)
306 FORMAT(16I5)
IF(IPR.EQ.0)GO TO 3000
WRITE(6,306)(NSP(J),J=1,ISPT)
WRITE(6,306)(NSPE(J),J=1,ISFTE)
3000 IKT = IKK
DO 99 IK = 1,IKK
WK = (2,PI)/(XK(IK)*SQRT(DH*32.2))
WRITE(6,73) XK(IK),WK
73 FORMAT(1H1,/,25X,24H WAVE PERIOD IN SECONDS =,F10.2,24X,9HWAVE NO
1=,E12.5,/)
IF( IK .GT. 1) GO TO 98
CALL INPUT2( X,Y,NOD,NCON
1,NELE,NNOD,NODR,NCS,NEQT,NBAND,NCS2,DD,IDPC,DH,IDCH)
CALL BAND( NCON
1,NELE,NNOD,NODR,NCS,NEQT,NBAND,NCS2)
98 CONTINUE
CALL ASEHKK(X,Y,NCON,YSK,YSQ,SYTP,NLGL
1,NELE,NNOD,NODR,NCS,NEQT,NBAND,NCS2,DD, NELE3
1,NLGL,IDPC,IBUGA)
IF(IBUGA.EQ.0)GO TO 3050
WRITE(6,350)
350 FORMAT(//,1X,13HELK ASSEMBLED)
3050 CONTINUE
CALL GSPK(SYTP,XJ,XY,XH,DH,ANGL
1,NELE,NNOD,NODR,NCS,NEQT,NBAND,NCS2,NODR1,VJ,VY,NLCL,IBUGG)
IF(IBUGG.EQ.0)GO TO 3060
WRITE(6,355)
355 FORMAT(//,1X,13HGSPK COMPLETE)
3060 CONTINUE
CALL LOAD(SH,YSQ,XJ,DH,ANGL
1,NELE,NNOD,NODR,NCS,NEQT,NBAND,NCS2,NODR1,IBUGL)
IF(IBUGL.EQ.0)GO TO 3070
WRITE(6,375)
375 FORMAT(//,1X,13HLOAD COMPLETE)

```

Figure 28. (Sheet 2 of 23)

```

3070 CONTINUE
      CALL EARSOL (SYSK,SYSC,STMF,NLG,NBAND,NUMBLK,NEQT,
1 NLGG,SYTF,NLGL,FTEMP)
      WRITE(6,20)
20  FORMAT(////,45X,40(1H0)//,45X,
      *40H      THE SOLUTION OF THE SYSTEM      //,45X,40(1H0)///
1/1X,7HELEMENT,5X,13HAMPLIFICATION,19X,8HVELOCITY,14X,7HELEMENT,5X,
213HAMPLIFICATION,19X,8HVELOCITY,74X,2HOR,11X,6HFACTOR,16X,
310HCOMPONENTS,5X,9HMAGNITUDE,5X,2HOR,11X,6HFACTOR,16X,
410HCOMPONENTS,8X,9HMAGNITUDE,72X,4HNODE,4X,4HMAG.,8X,5HPHASE,9X,
51HU,11X,1HV,18X,4HNODE,4X,4HMAG.,8X,5HPHASE,9X,1HU,11X,1HV,///)
      N1 = NM00+1
      DO 22 I=1,NEQT
      AR=REAL(SYSC(I))
      AI = AIMAG(SYSC(I))
      AT(I) = ATAN2(AI,AR)
      AF(I) = SQRT(AR**2+AI**2)
      AF(I) = AF(I)/2.
22  CONTINUE
      G=32.2
      DO 4014 L=1,NELE
      DO 4008 J=1,3
      NR(J) = NCON(L,J)
4008  CONTINUE
      I1=NR(1)
      I2=NR(2)
      I3=NR(3)
      Y1=X(I1)
      X2=X(I2)
      X3=X(I3)
      Y1=Y(I1)
      Y2=Y(I2)
      Y3=Y(I3)
      B1= Y3-Y2
      B2= Y1-Y3
      B3= Y2-Y1
      C1= X2-X3
      C2= X3-X1
      C3= X1-X2
      AREA=0.5*(B1*C2-B2*C1)
      FAC=2.*AREA/G
      LUM= L
      LUM1=3*LUM-2
      LUM2=3*LUM-1
      LUM3=3*LUM
      DV1L1 = -B1/FAC
      DV1L2 = -B2/FAC
      DV1L3 = -B3/FAC
      DV2L1 = -C1/FAC
      DV2L2 = -C2/FAC
      DV2L3 = -C3/FAC
      IF( AREA .GT. 0. ) GO TO 4009
      WRITE(6,4010) AREA,LUM
4010  FORMAT(1X,21HDEBUG ELNK 100, AREA=E12.5,6H      AT,I5,11H-TM ELEMEN
1T)
      STOP
4009  CONTINUE
      SYTF(LUM1)= (0.0,1.0)*DV2L1
      SYTF(LUM1)= SYTF(LUM1) + DV1L1
      SYTF(LUM2)= (0.0,1.0)*DV2L2
      SYTF(LUM2)= SYTF(LUM2) + DV1L2
      SYTF(LUM3)= (0.0,1.0)*DV2L3
      SYTF(LUM3)= SYTF(LUM3) + DV1L3
4014  CONTINUE
      K11=0
      SIGNA= 2.4*FAI/XR(IK)

```

Figure 28. (Sheet 3 of 23)

```

DO 250 J=1,NELE
DO 260 L=1,3
N=NCON(J,L)
260 Z(L)=AF(N)*2.
U(J)=0.0
V(J)=0.0
DO 270 L=1,3
K11=K11+1
DV1= REAL( SYTF(K11) )
DV2= AIMAG( SYTF(K11) )
U(J)= U(J)+DV1*Z(L)
270 V(J)= V(J)+DV2*Z(L)
U(J)=-U(J)/SIGMA
V(J)=-V(J)/SIGMA
250 YC(J)=SQRT(U(J)*U(J)+V(J)*V(J))
IF(IFC.EQ.0)GO TO 502
WRITE(6,30)
30 FORMAT(/,36X,61HELEVATION AND VELOCITY FOR SELECTED ELEVATION STAT
IONS(NODES),///)
DO 500 I=1,ISFT,2
II= I+1
J= NSF(I)
IF(II.GT.ISFT)GO TO 501
J1= NSF(J1)
WRITE (6,25) J,AF(J),AT(J),U(J),V(J),YC(J),J1,AF(J1),AT(J1),U(J1),
1V(J1),YC(J1)
GO TO 500
501 WRITE (6,24) J,AF(J),AT(J),U(J),V(J),YC(J)
500 CONTINUE
502 NSK2= 2*NSKIP
IF(IREDFT.EQ.1)WRITE(6,505)NSKIP
505 FORMAT(///,39X,32HELEVATION AND VELOCITY AT EVERY ,I3,19H-TH NODE
1OR ELEMENT,///)
DO 400 I=1,NNOD,NSK2
II= I+NSKIP
IF(II.GT.NNOD)GO TO 410
WRITE (6,25) I,AF(I),AT(I),U(I),V(I),YC(I),II,AF(II),AT(II),U(II),
1V(II),YC(II)
GO TO 400
410 WRITE (6,24) I,AF(I),AT(I),U(I),V(I),YC(I)
400 CONTINUE
NNOD1=NNOD+1
WRITE(6,23)
DO 414 I=NNOD1,NEQT,2
II= I+1
IF(II.GT.NEQT)GO TO 415
WRITE (6,25) I,AF(I),AT(I),U(I),V(I),YC(I),II,AF(II),AT(II),U(II),
1V(II),YC(II)
GO TO 414
415 WRITE (6,24) I,AF(I),AT(I),U(I),V(I),YC(I)
414 CONTINUE
WRITE(6,26)NSKIP
26 FORMAT(///,43X,20HVELOCITIES FOR EVERY,I3,22H-TH REMAINING ELEMEN
1T,///)
NECT1=NECT+1
NSK3= 3*NSKIP
DO 417 I= NECT1,NELE,NSK3
J1= I
J2= I + 2*NSKIP
IF(J2.GT.NELE)J2= NELE
WRITE(6,222)(J,U(J),V(J),YC(J),J-J1,J2,NSKIP)
222 FORMAT(1X,3(15,1X,3E12.5,2X))
417 CONTINUE
IF(IFC.EQ.0)GO TO 520
WRITE(6,31)
31 FORMAT(///,42X, 49HVELOCITY FOR SELECTED VELOCITY STATI

```

Figure 28. (Sheet 4 of 23)

```

IONS(ELEMENTS),///)
DO 515 I=1,ISFTE,3
II = I + 1
III = I + 2
J = NSFE(I)
IF(II.GT.ISFTE)GO TO 516
J1 = NSFE(II)
IF(III.GT.ISFTE)GO TO 517
J2 = NSFE(III)
WRITE(6,222)J,U(J),V(J),YC(J),J1,U(J1),V(J1),YC(J1),J2,U(J2),V(J2)
1,YC(J2)
GO TO 515
516 WRITE(6,223)J,U(J),V(J),YC(J)
GO TO 515
517 WRITE(6,221)J,U(J),V(J),YC(J),J1,U(J1),V(J1),YC(J1)
515 CONTINUE
221 FORMAT(1X,2(15,1X,3E12.5,2X))
223 FORMAT(1X,1(15,1X,3E12.5,2X))
2071 FORMAT(9H SOLUTION)
2022 FORMAT(4(1X,14,1X,2F7.3))
2023 FORMAT(5(2X,14,1X,F8.3))
23 FORMAT(/,60X,13HSOURCE POINTS,/)
24 FORMAT(1X,15,5E12.5)
25 FORMAT(1X,2(15,5E12.5))
520 IF((IPC.NE.0).OR.(IPMAX.NE.0))CALL CPUNCH(NODPT,IPMAX,AF,U,V,NMOD,
1NELE,NEQT,XK,IK,NSP,ISPT,IPER,ID,IPC,NSFE,ISFTE,IKT)
99 CONTINUE
STOP
END
*DECK CFUN
SUBROUTINE CFUNCH(NODPT,IPMAX,AF,U,V,NMOD,NELE,NEQT,XK,IK,NSP,ISPT
1,IPER,ID,IPC,NSFE,ISFTE,IKT)
C*****
C THIS SUBROUTINE PUNCHES CARDS FOR AMPLIFICATION AND VELOCITY
C*****
DIMENSION AF(NEQT),U(NELE),V(NELE),XK(25),ID(20),NSP(100),IPER(5),
1AFT(5),NSFE(100),UT1(3),VT1(3)
WRITE(6,101)
101 FORMAT( 4H 'C ')
WRITE(6,10)ID
10 FORMAT(20A4)
IF(IPC.EQ.0)GO TO 999
WRITE(6,50)ISPT,ISFTE,IKT
50 FORMAT(1X,3I5)
ISP = ISPT/5
FISPT = FLOAT(ISPT)
FISP = FISPT/5.0
IF(FISP.GT.ISP)ISP = ISP+1
ICOUNT = 0
J1 = 0
J2 = 0
DO 110 I=1,ISP
ICOUNT = ICOUNT +1
J1 = J2 + 1
J2 = J1 + 4
IF(J2.GT.ISPT)J2 = ISPT
N1 = 0
DO 112 J = J1,J2
N1 = N1 + 1
N = NSFE(J)
112 AFT(N1) = AF(N)
WRITE(6,111)ICOUNT,XK(1K),(AFT(N),N=1,N1)
111 FORMAT(1X,15,F10.5,3F13.4)
110 CONTINUE
ISFE = ISFTE/3
FISFTE=FLOAT(ISFTE)

```

Figure 28. (Sheet 5 of 23)



```

FISPE=FISPE/3.0
IF (FISPE.GT.ISPE) ISPE=ISPE+1
K1 = 0
K2 = 0
ICT = 0
DO 120 I=1,ISPE
  ICT = ICT + 1
  K1 = K2 + 1
  K2 = K1 + 2
  IF (K2.GT.ISPTE) K2 = ISPTE
  M1 = 0
  DO 113 N=K1,K2
    M1 = M1 + 1
    J = NSPE(K)
    UT1(M1) = U(J)
113  VT1(M1) = V(J)
    WRITE(6,114) ICT,XK(IK),(UT1(N),VT1(N),M=1,M1)
114  FORMAT(1X,I4,F10.3,6F11.4)
120  CONTINUE
    WRITE(6,150)
150  FORMAT(1X)
    WRITE(6,102)
102  FORMAT(4H 'L ')
    IF (IPMAX.NE.0) GO TO 1000
    RETURN
999  IF (IPMAX.EQ.0) GO TO 2000
1000 IC = 0
    WRITE(6,1010) (IPER(I),I=1,5),XK(IK)
1010  FORMAT(1X,5A4,F10.5)
    DO 1100 I=1,NNOD,11
      IC=IC + 1
      L1=I
      L2=L1 + 10
      IF (L2.GT.NNOD) L2 = NNOD
      WRITE(6,20) IC,(AF(L),L=L1,L2)
20  FORMAT(1X,I4,2X,11F6.3)
1100  CONTINUE
      DO 1200 I = 1,NELE,5
        IC = IC + 1
        L1 = I
        L2 = L1 + 4
        IF (L2.GT.NELE) L2 = NELE
        WRITE(6,30) IC,(U(L),V(L),L=L1,L2)
30  FORMAT(1X,I4,2X,5(2F7.3))
1200  CONTINUE
        WRITE(6,150)
2000  WRITE(6,102)
        RETURN
      END
*DECK INPT
      SUBROUTINE INPUT2( X,Y,NOD,NCON
1,NELE,NNOD,NODR,NCS,NEGT,NBAND,NCS2,DD,IDFC,DM,IDCH)
C*****
C THIS READS THE INPUT DATA FOR 3-NODES TRIANGLE ELEMENTS
C*****
COMMON/DB/ WK,ALPHA,D1,DA2,DA4,RR,WR,XL,WL,RKHF,HKL
DIMENSION X(NNOD),Y(NNOD),NOD(NNOD),NCON(NELE,3),DD(NELE)
C*****
C NOD(I)=EXTERNAL NODE NUMBER, IE, ACTUAL NODE NUMBER ASSIGNED
C X(I), Y(I)= X-AND Y-COORDINATES OF NOD(I)
C NCON(M,N)=M-TH-ELEMENT NODAL CONNECTIVITIES N=I-J-K
C*****
      NODB1=NNOD-NODR+1
      NODB2=NNOD-NODR
      DO 18 I=NODB1,NNOD
        IF (IDFC.NE.0) DD(I)=DM

```

Figure 28. (Sheet 6 of 23)

```

      NOD(I)=I
      II I=NODB1+1
      NA=II
      AAD=(II-1)*DA2
      X(I)=RR*COS(AAD)
      Y(I)=RR*SIN(AAD)
19  CONTINUE
      CALL GDEPTH(IDFC,DD,NNOD,NODB2,NELE,IDCH)
      DO 315 I=1,NODB2,2
      II=I+1
      IF(I.EQ.NODB2) GO TO 3314
      READ(4,316) NOD(I),X(I),Y(I),NOD(II),X(II),Y(II)
      GO TO 315
3314 READ(4,3316) NOD(I),X(I),Y(I)
315  CONTINUE
      IF(IDCH.EQ.1)PRINT 316,(NOD(I),X(I),Y(I),I=1,NNOD)
316  FORMAT( 2(I10,2F10.2) )
3316 FORMAT( I10,2F10.2 )
      IF(IDFC.NE.0)GO TO 400
      DD(I) = DD(I)/DM
      DO 60 I=1,NELE
      60  CONTINUE
      GO TO 70
400  DO 56 I = 1,NNOD
      DD(I) = DD(I)/DM
      56  CONTINUE
      70  DO 415 L = 1,NELE,4
      L1= L
      L2= L1 +3
      IF(L2.GT.NELE) L2= NELE
415  READ(4,416) ((NCON(LL,J),J=1,3),LL=L1,L2)
416  FORMAT( 4(5X,315) )
      IF(IDCH.EQ.1)PRINT 416,((NCON(L,J),J=1,3),L=1,NELE)
      RETURN
      END
*DECK DEPTH
      SUBROUTINE GDEPTH(IDFC,DD,NNOD,NODB2,NELE,IDCH)
C*****
C      THIS SUBROUTINE READS DEPTH AT EACH GRID NODE FROM CARDS OR USES
C      SPECIAL PROCEDURES TO READ AVER. DEPTH FOR EACH ELEMENT
C*****
      DIMENSION DD(NELE)
      IF(IDFC.NE.0)GO TO 1000
      SPECIAL PROCEDURE FOR INPUT OF AVER DEPTH FOR EACH ELEMENT
      DO 100 I = 1,121
      DD(I) = 24.
      100 CONTINUE
      DO 101 I=122,125
      DD(I) = 24.
      101 CONTINUE
      DO 102 I=126,318
      DD(I) = 24.
      102 CONTINUE
      DO 103 I=319,336
      DD(I) = 24.
      103 CONTINUE
      DO 104 I=337,360
      DD(I) = 29.5
      104 CONTINUE
      DO 105 I=361,371
      DD(I) = 24.
      105 CONTINUE
      DO 106 I=372,385
      DD(I) = 40.
      106 CONTINUE
      DO 107 I=386,529

```

Figure 28. (Sheet 7 of 23)

```

      DD(I)=21.
107 CONTINUE
      DO 108 I=530,2232
      DD(I) = 38.
108 CONTINUE
      DO 109 I = 2233,2333
      DD(I) = 42.
109 CONTINUE
      DD(2334) = 38.
      IF(IDCH.EQ.1)PRINT 2010,(DD(I),I=1,NELE)
2010 FORMAT(//,(12F10.3))
      GO TO 2000
C      READ DEPTH AT EACH NODE FROM CARDS OF PERM FILE
      527 FORMAT(8(I5,F5.0))
1000 READ(4,527)(I,DD(I),I=1,NNOB2)
      IF(IDCH.EQ.1)PRINT 2010,(DD(I),I=1,NNOB)
2000 RETURN
      END
*DECK BAND
      SUBROUTINE BAND( NCON
      1,NELE,NNOB,NODR,NCS,NEQT,NBAND,NCS2)
      DIMENSION NCON(NELE,3)
C*****
C      THIS SUBROUTINE DETERMINES THE BANDWIDTH FOR TRIANGLE ELEMENTS
C*****
      MPS= NODR+NCS
      KMAX=1
      DO 74 L=1,NELE
      IMAX=NCON(L,1)
      IMIN=NCON(L,1)
      DO 72 K=1,3
      IF(NCON(L,K) .LE. IMIN) IMIN=NCON(L,K)
      IF(NCON(L,K) .GE. IMAX) IMAX=NCON(L,K)
72 CONTINUE
      KK=IMAX-IMIN
      IF(KK .GT. KMAX) KMAX=KK
74 CONTINUE
      NBAND=KMAX+1
      NBAND=AMAX0(NBAND,MPS)
      WRITE(6,84)NBAND,NBAND,MPS
84 FORMAT(///1X,40(1H),/12H BAND WIDTH=,IS,/27H BAND WIDTH W.R.T. E
1LEKENT=,IS,/34H BAND WIDTH W.R.T. SOURCE + BDARY=,IS,/1X,40(1H),/
2)
      RETURN
      END
*DECK ASBK
      SUBROUTINE ASBK(X,Y,NCON,SYSK,YSQ
      1,ST,NGL
      1,NELE,NNOB,NODR,NCS,NEQT,NBAND,NCS2,DD,
      1,NLGG,IPPC,IBUG)
C*****
C      THIS SUBROUTINE ASSEMBLES ELK(I,J) ---ELEMENT--- INTO SYSK(I,J) --
C      - SYSTEM ---.
C      ELK= ELEMENT STIFFNESS MATRIX 3 BY 3
C      SYSK= SYSTEM STIFFNESS MATRIX NEQT BY NBAND
C*****
      COMPLEX SYSK,YSQ,ST
      COMMON/DB/WK,ALPHA,D1,DA2,DA4,RR,WF,XL,WL,RKHF,HKL
      DIMENSION X(NNOB),Y(NNOB),NCON(NELE,3),YSQ(NEQT)
      COMMON /NEW/ NUMBLK,NLG,NLGL,L11,LQ,L4,L3
      DIMENSION NR(3),ELK(3,3),DD(NELE)
      DIMENSION NR(3)
      DIMENSION ST(NGL,NBAND)
C      CHANGES
      DIMENSION SYSK(NLGG,NBAND)
      LEVEL 2,SYSK,YSQ,ST

```

Figure 28. (Sheet 8 of 23)

```

DO 122 I=1,NEQT
122 SYSQ(I)=(0.0,0.0)
L2=0
C   CHANGES
L3=NLG+NBAND*2
LQ=NLG*2
DO 888 IQ=1,NUMBLK
LEN=NLG
IF (IQ.EQ. NUMBLK) LEN=NLGL
L2=L2+LEN
L1=(IQ-1)*NLG+1
L11=L1-1
DO 12 I=1,LEN
C   CHANGES MADE
DO 12 J=1,NBAND
IF (IQ.NE. NUMBLK) GO TO 7176
ST(I,J)=(0.0,0.0)
GO TO 12
7176 CONTINUE
SYSK(I,J)=(0.0,0.0)
12 CONTINUE
DO 25 L=1,NELE
IGO=1
DO 14 J=1,3
NR(J)=0
NR(J)=NCON(L,J)
IF ((NR(J).LT.L1).OR.(NR(J).GT.L2)) GO TO 14
IGO=2
NR(J)=1
14 CONTINUE
IF (IRUG.EQ.0) GO TO 1000
WRITE(6,10)(NCON(L,J),J=1,3)
10 FORMAT(1X,4H****,3I10,4H****)
1000 GO TO (25,44),IGO
44 I1=NR(1)

I2=NR(2)
I3=NR(3)
X1=X(I1)
X2=X(I2)
X3=X(I3)
Y1=Y(I1)
Y2=Y(I2)
Y3=Y(I3)
IF (IDPC.NE.0) GO TO 210
D9 = DD(L)
GO TO 200
210 D11=DD(I1)
D12=DD(I2)
D13=DD(I3)
D9=(D11+D12+D13)/3.
IF (L.GE.1435.AND.L.LE.1571) D9=0.5
C*****
C***** SPECIAL STATEMENTS MAY BE ADDED TO COMPENSATE FOR *****
C***** AVERAGING PROCEDURE, FOR EXAMPLE, AS ABOVE-- *****
C*** IF (L.GE.1435.AND.L.LE.1571) D9 = 0.5 *****
C***** *****
200 DIN = 1.0
CALL ELNK(X1,X2,X3,Y1,Y2,Y3,WK,D9,DIN,ELK,AREA,L, NELE3)
IF (IRUG.EQ.0) GO TO 1050
WRITE(6,15)((ELK(H,N),N=H,3),H=1,3)
15 FORMAT(6E15.6)
1050 DO 20 I=1,3
DO 18 J=1,3
IF (NR(J)-NR(I).GE.0) GO TO 16
IF (NR(J).EQ.0) GO TO 18

```

Figure 28. (Sheet 9 of 23)

```

      LR=NR(I)-NR(J)+1
      J1=NR(J)-L11
      IF (IQ .NE. NUMBLK) GO TO 7177
      ST(J1,LR)=ST(J1,LR)+ELK(I,J)
      GO TO 18
7177 CONTINUE
      SYSK(J1,LR)=SYSK(J1,LR)+ELK(I,J)
      GO TO 18
      16 IF (NR(I) .EQ. 0) GO TO 18
      LS=NR(J)-NR(I)+1
      J2=NR(I)-L11
      IF (IQ .NE. NUMBLK) GO TO 7178
      ST(J2,LS)=ST(J2,LS)+ELK(I,J)
      GO TO 18
7178 CONTINUE
      SYSK(J2,LS)=SYSK(J2,LS)+ELK(I,J)
      18 CONTINUE
      20 CONTINUE
      25 CONTINUE
      IF (IQ .EQ. NUMBLK) GO TO 888
      L4=IQ+10
      CALL ECWR(SYSK,L4,L3,IERR)
      IF (IERR.EQ.1) GO TO 999
      888 CONTINUE
      544 RETURN
      999 PRINT 777
      777 FORMAT(20H WRITE ERROR IN ABSK )
      STOP
      END
*DECK GSPK
      SUBROUTINE GSPK(SYSK,XJ,XY,XH,DH,ANGL
      1,NELE,NMOD,NODR,NCS,NEQT,NBAND,NCS2,NODR1,VJ,VY,NLGG,IBUG)
      C      CHANGES MADE
      C*****
      C      THIS SUBROUTINE OBTAINS MATRIX K2 + K3, AND STORES IN THEIR
      C      CORRESPONDING ADDRESSES IN SYSK(I,J)
      C*****
      C      COMPLEX XH,DH,TH,SYSK
      C      COMMON/DB/ WK,ALPHA,D1,DA2,DA4,RR,WR,XL,WL,RKHP,HKL
      C      DIMENSION SYSK(NLGG,NBAND),XJ(NCS),XY(NCS),XH(NCS),DH(NCS)
      C      1,ANGL(NODR1)
      C      DIMENSION VJ(1),VY(1)
      C      LEVEL 2,SYSK
      C      COMMON /NEW/ NUMBLK,NLG,NLGL,L11,LS
      C      1,L4,L3
      C*****
      C      OBTAIN BESSEL FCN XJ,XY,XH,DH
      C*****
      WR= WK*RR
      XL= RR*DA2
      WL= WK*XL
      DO 12 I=1,NCS
      II=I-1
      FNU=0.
      CALL BESSY(WR,FNU,II,VJ,VY)
      XJ(I)=VJ(I)
      XY(I)=VY(I)
      IF (IBUG.EQ.0) GO TO 12
      WRITE(6,20) XJ(I),XY(I)
      12 CONTINUE
      DO 15 I=1,NCS
      XN= FLOAT(I-1)/WR
      XH(I)=XJ(I)+(0.0,1.0)*XY(I)
      IF (I .NE. 1) GO TO 9
      DH(1)=-XJ(2)-(0.0,1.0)*XY(2)
      GO TO 10

```

Figure 28. (Sheet 10 of 23)

```

9 DH(I)=(XJ(I-1)-XN*XJ(I))+(0.0,1.0)*(XY(I-1)-XN*XY(I))
10 CONTINUE
  IF (IBUG.EQ.0) GO TO 15
  WRITE(6,20) XH(I),DH(I)
15 CONTINUE
20 FORMAT(9H GSPK BY=,4E15.6)
1520 FORMAT (20H BLOCK ERROR IN GSPK ,I5)
C*****
C  STORE THE UPPER TRIANGLE ELEMENT OF K2 IN CORRESPONDING ADDRESSES
C  IN SYSK(I,J)
C*****
RKHP= 3.14159265*WR*D1
DO 38 I=1,NCS
  I1=NNOD+I-L11
  NLLL=1
  IF (I1.LE.0 .OR. I1.GT.NLGG) GO TO 1551
  CX=0.5
  IF (I.EQ.1) CX=1.0
  SYSK(I1,1)=SYSK(I1,1)+CX*RKHP*XH(I),*DH(I)
38 CONTINUE
C*****
C  STORE K3 IN CORRESPONDING ADDRESS IN SYSK(I,J)
C*****
DO 40 I=1,NODR1
40 ANGL(I)=(I-1)*DA2+DA4
  HKL=WL*D1/2.
  N1=NNOD-NODR
  DO 48 I=1,NODR
    II=N1+I-L11
    NLLL=2
    IF (II.LE.0 .OR. II.GT.NLGG) GO TO 1551
    I1=I-1
    NODR1=NODR+1-I
    DO 48 J=1,NCS
      JJ=NODR1+J
      IF (J.GT.1) GO TO 42
      TH=HKL*DH(I)
      IF (I.GT.1.AND.I.LT.NODR) TH=2.0*TH
      GO TO 46
42 J2=J-1
      IF (I.LE.1.OR.I.GE.NODR) GO TO 51
      A1=ANGL(I)*J2
      A2=ANGL(I1)*J2
      TH=HKL*DH(J)*(COS(A2)+COS(A1))
      GO TO 46
51 IF (I.EQ.NODR) GO TO 52
      A1=ANGL(I)*J2
      TH=HKL*DH(J)*COS(A1)
      GO TO 46
52 A2=ANGL(I1)*J2
      TH=HKL*DH(J)*COS(A2)
46 SYSK(II,JJ)=SYSK(II,JJ)-TH
48 CONTINUE
  IF (NUMBLK.EQ.1) RETURN
  L5=NLGG*MBAND*2
  L6=L4+1
  CALL ECWR(SYSK,L6,L5,IERR)
  IF (IERR.EQ.1) GO TO 2000
  IF (IBUG.EQ.0) GO TO 3000
  PRINT 1018, (SYSK(I,1),SYSK(I,2),I=1,NLGG,4)
1018 FORMAT (1X,4G14.3)
3000 RETURN
2000 PRINT 999
  999 FORMAT (20H WRITE ERROR IN GSPK )
  STOP
1551 PRINT 1520, NLLL

```

Figure 28. (Sheet 11 of 23)

```

      STOP
      END
*DECK LOAD
      SUBROUTINE LOAD(SM,SYSD,XJ,DH,ANGL
      1,NELE,NNOD,NODR,NCS,NEQT,NBAND,NCS2,NODR1,IRUG)
C*****
C      THIS SUBROUTINE GIVES LOADING TERMS @ SYSD(I)
C*****
      COMPLEX DUMY,SM,SYSD,DH,TM,CM,DUM2
      COMMON/DE/ WK,ALPHA,D1,D2,D3,RR,WR,XL,WL,RKHP,HKL
      DIMENSION SM(NODR1),SYSD(NEQT),DH(NCS),XJ(NCS),ANGL(NODR1)
      LEVEL 2,SYSD
      DWL=0.5*D1*WL
C*****
C      CALCULATE LOADING TERMS W.R.T. NODAL POTENTIAL + STORE IN SM(I)
C      AND THEN IN SYSD(I)
C*****
      DO 12 I=1,NODR1
        THETA= ANGL(I)
        CX=COS(THETA-ALPHA)
        AUG=WR*CX
        DUMY=COS(AUG)+(0.0,1.0)*SIN(AUG)
        C2=COS(THETA+ALPHA)
        AU2=WR*C2
        DUM2=COS(AU2)+(0.0,1.0)*SIN(AU2)
        SM(I)=DWL*(0.0,1.0)*(CX*DUMY+C2*DUM2)
      12 CONTINUE
      IF(IRUG.EQ.0)GO TO 100
      WRITE(6,8)(SM(I),I=1,NODR)
      8 FORMAT(//,(7E15.7))
      100 N1 = NNOD-NODR
      DO 14 I=1,NODR
        I1=N1+I
        IF(I.EQ.1) GO TO 14
        IF(I.EQ.NODR) GO TO 15
        I1=I-1
        SYSD(I1)=SYSD(I1)+SM(I)+SM(I1)
        GO TO 14
      14 SYSD(I1)=SYSD(I1)+SM(1)
        GO TO 14
      15 SYSD(I1)=SYSD(I1)+SM(NODR1)
      16 CONTINUE
      IF(IRUG.EQ.0)GO TO 110
      WRITE(6,8)(SYSD(I),I=1,NNOD)
C*****
C      CALCULATE LOADING TERMS W.R.T. SOURCES AND STORE IN SYSD(I)
C*****
      110 RKHP2=2.0*RKHP
      DO 40 I=1,NCS
        NNI=NNOD+I
        II=I-1
        AI=ALPHA*II
        CM=(0.0,1.0)**II
        TM=CM*XJ(I)*DH(I)*COS(AI)
        SYSD(NNI)=SYSD(NNI)-RKHP2*TM
      40 CONTINUE
      RETURN
      END
*DECK ELMT
      SUBROUTINE ELMT(X1,X2,X3,Y1,Y2,Y3,WK,D,DIN,ELK,AREA,LUM,
      1NELE3)
C*****
C      GENERATION OF TRIANGLE ELEMENT MATRIX ELK
C      DIN=1.0 IF IN OUTER DOMAIN? D=D1, HELMOLTZ EQ.
C      DIN=0.0 IF UNDER FLOATING BODY? D=D2, LAPLACE EQ.
C*****

```

Figure 28. (Sheet 12 of 23)

```

      DIMENSION ELK(3,3)
      DO 8 I=1,3
      DO 8 J=1,3
8     ELK(I,J)= 0.
      B1= Y3-Y2
      B2= Y1-Y3
      B3= Y2-Y1
      C1= X2-X3
      C2= X3-X1
      C3= X1-X2
      AREA=0.5*(B1*C2-B2*C1)
      G=32.2
      FAC=2.*AREA/G
      LUM1=3*LUM-2
      LUM2=3*LUM-1
      LUM3=3*LUM
      IF( AREA .GT. 0. ) GO TO 10
      WRITE(6,100) AREA,LUM
100  FORMAT(1X,23H DEBUG ELNK 100, AREA =,E12.5,5H   AT,15,11H-TH ELEME
      INT)
      STOP
10  A4=4.*AREA
      WKVD=WK
      WK=WK/SQRT(D)
      WKA= DIN*WK*WK*AREA/12.
      ELK(1,1)= ((B1*B1+C1*C1)/A4-2.*WKA)*D
      ELK(1,2)= ((B1*B2+C1*C2)/A4- WKA)*D
      ELK(1,3)= ((B1*B3+C1*C3)/A4- WKA)*D
C     ELK(2,1)=ELK(1,2)
      ELK(2,2)= ((B2*B2+C2*C2)/A4-2.*WKA)*D
      ELK(2,3)= ((B2*B3+C2*C3)/A4- WKA)*D
C     ELK(3,1)=ELK(1,3)
C     ELK(3,2)=ELK(2,3)
      ELK(3,3)= ((B3*B3+C3*C3)/A4-2.*WKA)*D
      WK=WKVD
      RETURN
      END
*DECK BESSY
      SUBROUTINE BESSY(X,FNU,H,BJ,BY)
C     BESSY NYU MATH UTILITY SUBROUTINE FOR BESSEL Y 3/15/64 F. RAGUSA
      DIMENSION BJ(1),BY(1)
C     DIMENSION BJ(1),BY(1)
      EQUIVALENCE(FH,MF)
C
      XSAVE=X
      M1=N
      MF=131070
      BJ(1)=FH
      CALL BESSJ(X,FNU,FH,BJ)
      BY(1)=FH
      YNU=BY(1)
      N=M1
      BY(2)=X
      X=XSAVE
C
      NN=IABS(N)
      N1=NN-1
      CONST=2.0/X
      FI=.314159265E+01
C
      IF(X-10.0) 30,19,19
30  X10=X+25.0
      K10=X10
      N10=NN+10
      M= MAX0(K10,N10)
C

```

Figure 28. (Sheet 13 of 23)



```

      IF (X - 1.0) 1, 1, 3
1  KP=172.69388/(3.6888795-ALOG(X))
   M=MINO(M,KP)
   GO TO 2
3  KP=39.0*X*.3333333
   M=MINO(M,KP)
2  M=M/2
   N=2*M+1
   ARG=FNU*PI
   GARG=GAMMA(1.0+FNU,0.0)**2
C
C   COMPUTE GAMMA ZERO EQU. 15,PG. 5 , IF NU=0 USE EQU. 16.
C
14 IF (FNU) 15,16,15
15 TERM=(1.0/PI)*CONST**(2.0*FNU)
   GAM1=COS(ARG)/SIN(ARG) - TERM*(GARG/FNU)
C   COMPUTE GAMMA ONE FOR NU NOT EQUAL ZERO.
   GAM2=2.0 * TERM * GARG * (FNU+2.0) / (1.0-FNU)
   GO TO 10
C
C   COMPUTE GAMMA ZERO AND ONE FOR NU EQUAL ZERO.
16 TLOG = ALOG(X/2.0)
   A=.577215664E+00
   PIH=2.0/PI
   GAM1=PIH*(A+TLOG)
   GAM2=4.0/PI
C
C   COMPUTE GAMMA, YNU, AND BY(1), AND BY(2)
C   EQUATIONS 15,17, AND 18.
C
10 BY(2)=0.0
   BY(1)=0.0
   GAM3=0.0
   E1=- (1.0/PI)*CONST**(1.0+2.0*FNU) * GARG
   BY(2)=E1*BJ(1)+BY(2)
   E1=GAM1-GAM2/2.0
   BY(2)=E1*BJ(2)+BY(2)
   YNU=GAM1*BJ(1)
   TXNU=3.0*FNU/X
   AB=ABS(BJ(1)) - .000005
   I2=1
   MP1=M+1
C
DO 11 I=2,MP1
  I2 = I2 + 2
  FI = I
  FIM = I-1
  FI2 = 2*FI
  DENOM = FI*(FI-FNU)*(FNU+FI2-2.0)
  GAM3 = (FNU+FI2)*(2.0*FNU+FIM)*(FNU+FIM)/DENOM
  GAM3 = -GAM3*GAM2
  YNU = GAM2*BJ(I2)+YNU
  IF(AB)18,18,23
  WHEN J(NU) IS NEAR ZERO COMPUTE BY(2) FROM EQ. 18,ELSE EQ. 17.
C
C
18 E1=TXNU*GAM2
   BY(2)=E1*BJ(I2)+BY(2)
   IF(I2-K) 25,110,110
25 E1=(GAM2-GAM3)/2.0
   BY(2)=E1*BJ(I2+1)+BY(2)
23 GAM1=GAM2
11 GAM2=GAM3
C
110 BY(1)=YNU
   IF(AB) 19,19,17
17 BY(2)=(YNU*BJ(2)-2.0/(FI*X))/BJ(1)

```

Figure 28. (Sheet 14 of 23)

```

C
C   IF N=0 OR 1 GO OUT ALL BY S COMPUTED.
19 IF(N) 30,49,20
20 IF(N-1) 49,49,21
C
C   COMPUTE Y(N+1) BY RECURRENCE
C
21 DO 22 I=1,N1
   FI1=1
22 BY(I+2)=CONST*(FI1+FNU)*BY(I+1)-BY(I)
C
49 RETURN
50 IF(FNU-.500000) 54,53,54
53 BY(2)=BJ(1)
   IF(NN-1) 49,61,60
60 ARG=-1.0
   BY(3)=ARG*BJ(2)
   BJ(2)=CONST*FNU*BJ(1)-BJ(2)
   ARG=-ARG
   IF (NN-2) 49,51,56
56 DO 55 I=2,N1
   BY(I+2)=ARG*BJ(I+1)
55 ARG=-ARG
   GO TO 51
54 BY(2)=CONST*FNU*BY(1)-BY(2)
   BJ(2)=CONST*FNU*BJ(1)-BJ(2)
   IF(NN-1) 49,49,51
51 FRAC=FNU
   DO 52 I=1,N1
   FRAC=FRAC-1.0
   BJ(I+2)=CONST*FRAC*BJ(I+1)-BJ(I)
   IF(FNU-.50000) 58,52,58
58 BY(I+2)=CONST*FRAC*BY(I+1)-BY(I)
52 CONTINUE
   GO TO 49
61 BJ(2)=CONST*FNU*BJ(1)-BJ(2)
   GO TO 49
   END
*DECK GAMA
FUNCTION GAMMA(U,V)
DIMENSION B(8)
B(1)= .035868343
B(2)=-.193527818
B(3)= .482199394
B(4)=-.756704078
B(5)= .918206857
B(6)=-.897056937
B(7)= .988205891
B(8)=-.577191652
A=U
X=V
XN=15.0
1 IF(A)4,2,3
2 IF(X-1.0)4000,4000,5000
4 Z = AINT(A)
Y=ABS(Z-A)
EPS=3.0E-8
IF(Y-EPS)21,21,5
21 A=Z
   GO TO 22
5 Y=1.0-Y
   IF(Y-EPS)6,6,3
6 A=Z-1.0
22 IF(X-1.0)4000,4000,5000
3 IF(X)7,1000,7
7 IF(X-1.0)9,9,8

```

Figure 28. (Sheet 15 of 23)

```

8 IF (A) 5000, 10, 10
10 IF ((X/A)-1.0) 1000, 5000, 5000
9 IF (ABS(A) -1.) 11, 1000, 1000
11 IF (X-.1) 1000, 12, 12
12 IF (X-.2) 13, 14, 14
13 XN=140.0
   GO TO 5000
14 IF (X-.4) 15, 16, 16
15 XN=80.0
   GO TO 5000
16 IF (X-.6) 17, 18, 18
17 XN=60.0
   GO TO 5000
18 IF (X-.8) 19, 20, 20
19 XN=40.0
   GO TO 5000
20 XN=20.0
5000 XFT=X
     N=XN
     DO 5001 I=1,N
     XFT=((XN/XFT)+1.0
     XFT=((XN-A)/XFT)+X
5001 XN=XN-1.0
     TEM = (ALOG(X)*A)-X
     GO TO 6000
4000 SUM=0.0
     ANS=XFT
     XFT = EXP(TEM)/XFT
     EPS=1.0E-8
     XM=1.0
     XMT=1.0
     EX=-1.0
     TEM=X
4001 Y= TEM/(XMT*XM)
4011 SUM=SUM+EX*Y
     IF (ABS(Y)-EPS) 4003, 4002, 4002
4002 TEM=TEM*X
     XM=XM+1.0
     XMT=XMT*XM
     EX=-EX
     GO TO 4001
4003 E=-ALOG(X)-.57721566-SUM
     IF (A) 4005, 4004, 4005
4004 ANS=E
     GO TO 6000
4005 IF (A+2.0) 4010, 4009, 4008
4008 ANS=-E+EXP(-X)/X
     GO TO 6000
4009 SUM=(1.0/X)-(1.0/(X*X))
     ANS=(E-EXP(-X)*SUM)*.5
     GO TO 6000
4010 EX=-1.0
     N=-A-1.0
     XMT=1.0
     SUM=0.0
     TEM=X
     DO 4006 I=1,N
     TEM=TEM*X
     XM=I+1
     Y=XMT/TEM
     SUM=SUM+EX*Y
     EX=-EX
4006 XMT=XMT*XM
     SUM=SUM+1.0/X
     Z=E-EXP(-X)*SUM
     Y=ABS(A)

```

Figure 28. (Sheet 16 of 23)

```

      EX=-1.0
      XMT=1.0
      N=Y
      DO 4007 I=2,N
      XM=1
      XMT=XMT*XM
4007  EX=-EX
      ANS=Z*EX/XMT
      GO TO 6000
1000  IF(A-1.0)1001,1003,1004
1004  IF(A-2.0)1003,1003,1002
1003  AT=A-1.0
      ATM=B(1)*AT
      DO 1005 I=2,8
1005  ATM=(ATM+B(I))*AT
      ANS=ATM+1.0
      GO TO 2000
1001  IF(A)1007,1006,1006
1006  BN=A
      BS=A
      GO TO 1010
1007  BN=A
      BS=A
1011  IF(BS)1009,1010,1010
1009  BS=BS+1.0
      BN=BS*BN
      GO TO 1011
1010  ATM=BS*B(1)
      DO 1012 I=2,8
1012  ATM=(ATM+B(I))*BS
      ANS=(ATM+1.0)/BN
      GO TO 2000
1002  BN=A-1.0
      BS=BN
1013  IF(2.0-BS)1015,1014,1014
1015  BS=BS-1.0
      BN=BS*BN
      GO TO 1013
1014  BS=BS-1.0
      ATM=BS*B(1)
      DO 1016 I=2,8
1016  ATM=(ATM+B(I))*BS
      ANS=(ATM+1.0)*BN
2000  IF(X)2001,6000,2001
2001  W=1.0
      XM=1.0
      SUM=1.0
      EPS=1.0E-8
2002  W=(X/(A+XM))*W
      SUM=SUM+W
      XM=XM+1.0
      IF (ABS(W)-EPS) 2003,2002,2002
2003  T=A*ALOG(X)
      T=EXP(T-X)/A
      ANS=ANS-(T*SUM)
6000  GAMMA=ANS
      RETURN
      END
*DECK BESSJ
      SUBROUTINE BESSJ(X,FNU,FN,F)
C      BESSJ NYU MATH UTILITY BESSEL J SUBROUTINE 3/15/64 F. RAGUSA
      DIMENSION F(1)
      EQUIVALENCE(FN,MF)
C
      N=FN
      NN=IABS(N)

```

Figure 28. (Sheet 17 of 23)

```

C   WHEN BESJ HAS BEEN CALLED BY BESY F(1) WILL CONTAIN INTERGER 131070
      FM=F(1)
      IY=1
      IF(KF-131070) 2,1,2
1    IY=2
2    CONST=2.0/X
C
      IF(X-50.0) 4,8,8
6    X10=X+25.0
      K10=X10
      N10=NN+10
40   M=MAX0(K10,N10)
C
      IF(X-1.0) 3,3,41
3    KP=-(172.69388/(3.6888795-ALOG(X)))-1.0
      M=NINO(M,KP)
      GO TO 4
41   KP=39.0*X**1.3333333
      M=NINO(M,KP)
4    M=M/2
43   K=2*M+1
      K2=K+1
      K3=K+2
      F(K2)=1.0E-35
      F(K3)=0.0
C
      DO5 L=1,K
      I=N+1-L
      FLI=I
5    F(I)=CONST*(FLI+FNU)*F(I+1)-F(I+2)
C
C   FIND ALPHA EITHER FROM EQUA. 12,PAGE 4 WHEN X IS LESS THAN 8.0
C   OR FROM BESSEL FUNCT. FOR LARGE ARGUMENTS WHEN X IS 8 OR GREATER.
C
      IF(X-10.0) 7,8,8
7    PHI=FNU+2.0
      ALF=PHI*F(3)+F(1)
      MO=3
C
      DO15 I=2,M
      MO=MO+2
      FM2=2*I
      FM1=I-1
      FI=I
      TEMP=((FNU+FM2)*(FNU+FM1))/(FI*(FNU+FM2-2.0))*PHI
      PHI=TEMP
15   ALF=PHI*F(MO)+ALF
C
      ALF=CONST*(FNU+GAMMA(FNU+1.0,0.0))*ALF
C
      I1=1
C
C   FIND J(N) EQUATION 7,PAGE 3,WHEN X LESS THAN 10.0
C   OR J(2),J(3),...,J(N)=F(2)/ALPHA,...,F(N)/ALPHA WHERE
C   ALPHA=F(1)/J(1) AND J(1) A*COS(PHI) FROM PATH 8.
C
16   DO17 I=I1,K
17   F(I)=F(I)/ALF
C   TEST FOR NEGATIVE N AND RECOMPUTE FS BY RECURSION.
      IF(N) 18,22,22
18   IF(IY=2) 19,22,19
19   F(2)=CONST*FNU*F(1)-F(2)
      IF(MN=1) 22,22,20
20   FRAC=FNU
      N1=MN+1
      DO 21 L=3,N1

```

Figure 28. (Sheet 18 of 23)

```

      FRAC=FRAC-1.0
21  F(L)=CONST4FRAC1F(L-1)-F(L-2)
C
C      IF ENTRY WAS FROM BESY RETURN A VALUE FOR Y(1) IN
C      PLACE OF N.IY WILL BE EQUAL TO 2 IN THIS CASE.
C
22  GO TO (24,23),IY
23  FN Y1
    X=Y2
24  RETURN
C
C      PATH B. WHEN X IS GREATER THAN OR = TO 10.0
C      COMPUTE J(1) FROM H.GOLDSTEIN PAPER BESSEL
C      FUNCTIONS FOR LARGE ARGUMENTS.
C
      B MOUNT-1
      GNU=FNU
      C0 =.25
      C1 =.15625
      C2 =-.375
      C3 =.1171875
      C4 =-1.15625
      C5 =1.875
      C6 =.952148437E-01
      C7 =-2.38671875
      C8 =14.2265625
      C9 =-19.68750
      C10=.809326171E-01
      C11=-.410058593E+01
      C12=.582246093E+02
      C13=-277.87500
      C14=354.3750
      C15=.416666666E-01
      C16=-.25
      C17=.125E-1
      C18=-.350
      C19=.558035718E-03
      C20=-.424107142E+00
      C21=3.60267857
      C22=-5.625
      C23=-.30381944E-02
      C24=-.486111
      C25=.102864583E+02
      C26=-58.0
      C27=78.75
9  A1=GNU**2-.25
    A2 =C0*A1
    A4 =C1*A1
    A4=(A4+C2)*A1
    A6=C3*A1
    A6=(A6+C4)*A1
    A6=(A6+C5)*A1
    A8=C6*A1
    A8=(A8+C7)*A1
    A8=(A8+C8)*A1
    A8=(A8+C9)*A1
    A10=C10*A1
    A10=(A10+C11)*A1
    A10=(A10+C12)*A1
    A10=(A10+C13)*A1
    A10=(A10+C14)*A1
C
    F1=.314159265F+01
    TS=1.0/X
    T2=TS**2
C

```

Figure 28. (Sheet 19 of 23)

```

      B=A10*T2+AB
      E=E*T2+A6
      E=E*T2+A4
      E=E*T2+A2
      BNU=E*T2+1.0
C
      ANU=BNU/SQRT(.5*PI*X)
C
C      PAGE 20, EQUATION 12 TO GET PHI ZERO
C
      A2=.5*AL1
      A4=C15*AL1
      A4=(A4+C16)*AL1
      A6=C17*AL1
      A6=(A6+C18)*AL1
      A6=(A6+.75)*AL1
      A8=C19*AL1
      A8=(A8+C20)*AL1
      A8=(A8+C21)*AL1
      A8=(A8+C22)*AL1
      A10=C23*AL1
      A10=(A10+C24)*AL1
      A10=(A10+C25)*AL1
      A10=(A10+C26)*AL1
      A10=(A10+C27)*AL1
C
      E=A10*T2+A8
      E=E*T2+A6
      E=E*T2+A4
      E=E*T2+A2
      TPhi=E*T2+1.0
      PHI=TPhi*X-(GNU+.5)*(PI/2.0)
      CDP=cos(PHI)
      SIP=sin(PHI)
C
      F1=ANU*CDP
      Y1=ANU*SIP
C
      IF(KOUNT-1) 10,10,11
C
10  FSAVE=F1
      YSAVE=Y1
      GNU=GNU+1.0
      KOUNT=2
      GO TO 9
C
11  F2=F1
      Y2=Y1
      F1=FSAVE
      Y1=YSAVE
C
      IF(X-50.0) 110,111,111
110 IF (ABS(F1) - ABS(F2)) 12,12,13
111 F(1)=F1
      F(2)=F2
      IF(N) 18,22,112
112 IF(N-1) 22,22,113
113 N1=NN+1
      FLI=0.0
      DO 114 I=3,N1
      FLI=FLI+1.0
114 F(I)=CONST*(FNU+FLI)*F(I-1)-F(I-2)
      GO TO 22
C
12 ALF=F(2)/F2
      GO TO 14

```

Figure 28. (Sheet 20 of 23)

```

C
13 ALF=F(1)/F1
14 F(1)=F1
   F(2)=F2
   I1=3
   GO TO 16
   END
*DECK BANDS
SUBROUTINE BANSOL(A,D,B,NN,MM,NUMBLK,NEQT,LLL,E,NLGL,F)
COMPLEX F
DIMENSION F(NN,MM)
COMPLEX A,B,D,C,E
DIMENSION A(LLL,MM),D(1),B(1),E(NLGL,MM)
LEVEL 2,A,D,B,E,F
NNN=LLL/2
NQ=NN*MM
NBL=NN
MQ=NQ*2
MQQ=MQ
NBAND=MM
NBLQ=NN
NR=0
GO TO 150
100 NR=NR+1
   IF (NUMBLK-NR-1) 103,104,101
104 MQQ=NN*MM*2
   NBLQ=NNN
   GO TO 101
103 NBL=NNN
C CHANGES
101 DO 125 N=1,NBL
   NM=NN+N
   B(N)=B(NM)
   B(NM)=0.0
   DO 125 M=1,MM
   A(N,M)=A(NM,M)
125 A(NM,M)=0.0
C NO CHANGES
   IF (NUMBLK-NR) 150,200,150
150 NQ=NBL+11
   IF (NBLQ-NN) 109,110,109
110 CALL FILL (A,F,B,D,NB,NN,NNN,NBAND,LLL,NQQ,MQQ)
   GO TO 126
109 CALL FILL (A,E,B,D,NB,NN,NNN,
1 NBAND,LLL,NQQ,MQQ)
126 IF (NB) 200,100,200
200 DO 300 N=1,NBL
   IF (CABS(A(N,1)) .LT. 1.0E-30) GO TO 999
225 B(N)=B(N)/A(N,1)
   DO 275 L=2,MM
   IF (A(N,L)) 230,275,230
230 C=A(N,L)/A(N,1)
   I=N+L-1
   J=0
   DO 250 K=L,MM
   J=J+1
250 A(I,J)=A(I,J)-C*A(N,K)
   B(I)=B(I)-A(N,L)*B(N)
   A(N,L)=C
275 CONTINUE
300 CONTINUE
   IF (NUMBLK-NR) 375,405,375
375 NQZ=(NB-1)+11
   NBNN=NB*NN
   DO 127 N=1,NN
   NC=NBNN+NN+N

```

Figure 28. (Sheet 21 of 23)



```

      D(NC)=B(N)
      DO 127 M=1,NBAND
127  F(N,M)=A(N,M)
      CALL ECWR(F,NQZ,MQ,IERR)
      IF (IERR.EQ. 1) GO TO 888
      GO TO 100
405  CONTINUE
400  DO 450 M=1,NBL
      N=NBL+1-M
      DO 425 K=2,MM
      L=M+K-1
425  E(N)=B(N)-A(N,K)*B(L)
      NM=N+MMN
      E(N+NM)=B(N)
450  A(NM,NB)=B(N)
      NB=NB-1
      NBL=NM
      IF (NB) 475,500,475
475  NQL=(NB-1)+11
      CALL ECRD(F,NQL,MQ,IERR)
      IF (IERR.EQ. 1) GO TO 777
      DO 136 M=1,NN
      NC=NB*NN-NN+N
      B(N)=D(NC)
      DO 136 M=1,NBAND
136  A(N,M)=F(N,M)
      GO TO 400
500  K=0
      DO 600 NB=1,NUMBLK
      IF (NB.EQ. NUMBLK) NBL=NNN
      DO 600 N=1,NBL
      NM=N+NNN
      K=K+1
600  D(K)=A(NM,NB)
555  RETURN
777  N=1
444  PRINT 666,N
666  FORMAT (10H ERROR NO.,I10)
      STOP
888  N=2
      GO TO 444
999  PRINT 998,A(N,1),N
998  FORMAT (13H DIAG TROUBLE ,5X,2G13.5,I5)
      STOP
      END
*DECK FILL
      SUBROUTINE FILL (A,E,B,D,NB,NM,NN,NBD,LLL,NQZ,MQ)
      COMPLEX A,B,D,E
      DIMENSION A(LLL,NBD),B(1),D(1),E(NN,NBD)
      LEVEL 2,A,E,B,D
      NBN=NB*NM
      CALL ECRD(E,NQZ,MQ,IERR)
      IF (IERR.EQ. 1) GO TO 999
      DO 1 N=1,NN
      NC=NB*N
      NNN=NN+N
      E(NNN)=D(NC)
      DO 1 M=1,NBD
1  A(NNN,M)=E(N,M)
      RETURN
999  N=3
      PRINT 666,N
666  FORMAT (10H ERROR NO. ,I5)
      STOP
      END
*DECK ECWR

```

Figure 28. (Sheet 22 of 23)

```

SUBROUTINE ECWR(S,L1,L2,IERR)
  DIMENSION S(1)
  LEVEL 2,S
  IERR = 0
  REWIND L1
  WRITE(L1) (S(I),I=1,L2)
  IF(UNIT(L1).GE.0.)IERR = 1
  RETURN
END
*DECK ECRD
SUBROUTINE ECRD(S,L1,L2,IERR)
  DIMENSION S(1)
  LEVEL 2,S
  IERR = 0
  REWIND L1
  READ(L1) (S(I),I=1,L2)
  IF((EOF(L1).NE.0).OR.(IOCHEC(L1).NE.0))IERR = 1
  RETURN
END

```

Figure 28. (Sheet 23 of 23)

DATA SET NO. 1CARD NO. 1

<u>Col.</u>	<u>Format</u>	<u>Variable Name</u>	<u>Description</u>
1 - 80	20A4	ID	This card contains alpha-numeric title that appears in the output for job identification

CARD NO. 2

1 - 5	I5	NBAND	NBAND equals either the maximum difference between two nodes or the sum of NCS and NODR, whichever is greater.
6 - 10	I5	IPR	IPR=1, input data check - echo printed IPR=2, echo not printed
11 - 20	F10.2	RR	Radius of the semicircle (feet)
21 - 30	F10.5	ALPHA	Wave angle of incidence
31 - 40	F10.5	DM	Water depth of the node on the semicircle
41 - 46	I6	IBLKLEN	The value of IBLKLEN should not exceed 31000

CARD NO. 3

1 - 5	I5	IPC	IPC=0, the elevation and velocity at selected elevation stations are omitted IPC=1, the values are printed
6 - 10	I5	IPMAX	IPMAX=0, subroutine CPUNCH will not be called
11 - 15	I5	IDPC	IDPC=0, special procedure for input of average depths for each element is used IDPC=1, read depth at each grid node from cards or from the data files
16 - 20	I5	IDCH	IDCH=1, element number, nodal point, and depth of each element and the x and y coordinates of each node are printed
21 - 25	I5	IBUGA	IBUGA=1, ELK (element stiffness matrix 3 x 3) are printed

<u>Col.</u>	<u>Format</u>	<u>Variable Name</u>	<u>Description</u>
26 - 30	I5	IBUGG	IBUGG=1, SYSK(1,1) and SYSK(1,2) are printed
31 - 35	I5	IBUGL	IBUGL=1, SYSO(I) are printed
36 - 40	I5	IDISP	IDISP=1, dispersion included
41 - 45	I5	ICIRC	ICIRC=0, for semicircle grid ICIRC=1, for circular grid
46 - 50	I5	NC	NC=0, selected elevation stations (nodes) will not be punched

CARD NO. 4

1 - 10	F10.2	TMIN	The minimum wave period (seconds)
11 - 20	F10.2	TDELT	The increment of wave period (seconds)
21 - 25	I5	IKK	The number of times of the increment

DATA SET NO. 2

CARD NO. 1

1 - 5	I5	NSP(1)	Selected elevation station number (nodes), starting from NSP(1) to NSP(ISPT)
6 - 10	I5	NSP(2)	Fourteen values on each card and continuing to the next card as needed
.			
.			
.			
.			
66 - 70	I5	NSP(14)	

DATA SET NO. 3

CARD NO. 1

1 - 5	I5	NSPE(1)	Selected elevation station number (element), starting from NSPE(1) to NSPE(ISPTE)
6 - 10	I5	NSPE(2)	Fourteen values on each card and continuing to the next card as needed

<u>Col.</u>	<u>Format</u>	<u>Variable Name</u>	<u>Description</u>
.			
.			
.			
66 - 70	I5	NSPE(14)	
<u>DATA SET NO. 4</u>			
<u>CARD NO. 1</u>			
1 - 10	F10.2	X(1)	x-coordinate at each nodal point, starting from X(1) to X(NNOD)
11 - 20	F10.2	X(2)	Eight values on each card and continuing to the next card as needed
.			
.			
.			
.			
71 - 80	F10.2	X(8)	
<u>DATA SET NO. 5</u>			
<u>CARD NO. 1</u>			
1 - 10	F10.2	Y(1)	y-coordinate at each nodal point, starting from Y(1) to Y(NNOD)
11 - 20	F10.2	Y(2)	Eight values on each card and continuing to the next card as needed
.			
.			
.			
.			
71 - 80	F10.2	Y(8)	

<u>Col.</u>	<u>Format</u>	<u>Variable Name</u>	<u>Description</u>
<u>DATA SET NO. 6</u>			
<u>CARD NO. 1</u>			
1 - 5	Blanks		
6 - 10	I5	NCON(1,1)	Node number of the first nodal point of element 1
11 - 15	I5	NCON(1,2)	Node number of the second nodal point of element 1
16 - 20	I5	NCON(1,3)	Node number of the third nodal point of element 1
21 - 25	Blanks		
26 - 30	I5	NCON(2,1)	Node number of the first nodal point of element 2, etc.
31 - 35	I5	NCON(2,2)	Nine values on each card, starting from NCON(1,1), NCON(1,2), and NCON(1,3) to NCON(NELE,1), NCON(NELE,2), and NCON(NELE,3), respectively, continuing to the next card as needed

.

.

.

.

56 - 60      I5      NCON(3,3)

DATA SET NO. 7\*

CARD NO. 1

1 - 10	F10.2	DD(1)	Depth at each nodal point, starting from DD(1) to DD(NNOD)
11 - 20	F10.2	DD(2)	Eight values on each card and continuing to the next card as needed

.

.

.

.

71 - 80      F10.2      DD(8)

\*Note: If IDPC=0, Data Set No. 7 is omitted. Depth of each node should be specified by user in the program FINITE.

## Procedure to Run Program FINITE

49. To set the correct values for the parameter statements in program FINITE, the following procedure should be followed.

- a. Sign on the Cybernet Computer System  
Telephone No. 2047 for 300 Baud  
Telephone No. 2030 for 1200 Baud
- b. Type in  
GET,FINITE/UN=CEROMO  
SAVE,FINITE
- c. Use XEDIT to set correct values for the parameters in the  
parameter statements  
Type in  
OLD,FINITE  
XEDIT
- d. Locate the first parameter statement  
Type in  
L/PARAMETER/  
The system will respond with  
PARAMETER(NNOD=35,NELE=48,NODR=9,NCS=7,ISPT=35,ISPTE=48)
- e. Change old values in the parameter statement to desired values  
Type in  
C/NNOD=35,NELE=48,NODR=9/NNOD=new value,NELE=new value,NODR=new  
value/  
C/NCS=7,ISPT=35,ISPTE=48/NCS=new value,ISPT=new value,ISPTE=new  
value/
- f. Locate the second parameter statement  
Type in  
N1  
The system will respond with  
PARAMETER(NSYSK=1394,NSYTP=772,NSTMP=84)
- g. Change the values in parameter statement to desired values  
Type in  
C/NSYSK=1394,NSYTP=772/NSYSK=new value,NSYTP=new value/  
C/NSTMP=84/NSTMP=new value/
- h. Replace program file FINITE by edited version  
Type in  
E,,RL

50. Establish an "AFFILE" on the CYBER 205 System. An "AFFILE" enables the Corps of Engineers (KOE) user to transmit files from KOE to the CYBER 205, and vice versa.

- a. Type in  
GET,AFJCL/UN=CEROMO  
SAVE,AFJCL

- b. Use XEDIT to make necessary changes  
Type in  
OLD,AFJCL  
XEDIT
- c. Replace 205USER with actual user's ID of the CYBER 205  
Type in  
C/205USER/USER'S 205 ID/
- d. Replace all PASSWORDS with the actual user's PASSWORD  
Type in  
C/PASSWORD/ACTUAL USER'S PASSWORD/\*
- e. Replace all KOEUSER with actual user's ID of the KOE  
Type in  
T  
This command will bring the pointer to the top of the file  
Type in  
C/KOEUSER/ACTUAL KOE USER'S ID/\*
- f. Replace file AFJCL with the edited version  
Type in  
E,,RL
- g. To execute file AFJCL  
Type in  
GET,ADYJOB/UN=CATHDDC  
BEGIN,,ADYJOB,AFJCL  
The system will respond with

ALL DONE. USER JOB NAME IS COEXXXX

(Note: The status of the job can then be tracked by using "LINK,ENQUIRE." When the job is complete, output will return to the users QGET queue and can be accessed by using the "QLIST" command.)

51. Establish file "QLIST", which enables the KOE users to retrieve CYBER 205 dayfiles and outputs.

- a. Type in  
GET,QLIST/UN=CEROM0  
SAVE,QLIST
- b. Use XEDIT to make necessary changes  
Type in  
OLD,QLIST  
XEDIT
- c. Replace old UID with new UID  
Type in  
C/UID=HASH/UID=XXXX/  
(XXXX is the user's index hash. It can be obtained from "ENQUIRE(B)."  
XXXX are the first four characters of the job name that the system  
assigned to the user.)
- d. Replace KOEUSER with user's ID  
Type in  
C/KOEUSER/USER'S ID/



- e. Replace old header with user's header  
Type in  
C/HEADER1/USER'S HEADER/  
C/HEADER2/USER'S HEADER/  
C/HEADER3/USER'S HEADER/
  - f. Replace file QLIST with the edited version  
Type in  
E,,RL
- 52. Create an Update Library
  - a. Type in  
GET,FINUP1/UN=CEROMO  
BEGIN,RUNF,FINUP1  
The system will respond with  
15.56.20 SUBMIT COMPLETE. JOB NAME IS AJZZXXX
  - b. Check dayfile  
Type in  
OLD,DAY1  
LIST
- 53. Establish an Update Correction File
  - a. Type in  
GET,FINDIR/UN=CEROMO  
SAVE,FINDIR
  - b. Use XEDIT to make necessary changes and replace the file FINDIR with the edited version
- 54. Run program FINITE with Update Correction File FINDIR (Figure 29).
  - a. Type in  
GET,FINI/UN=CEROMO  
SAVE,FINI
  - b. Use XEDIT to make necessary changes  
Type in  
OLD,FINI  
XEDIT
  - c. Replace 205USER with the CYBER 205 user's ID  
Type in  
C/205USER/CYBER 205 USER'S ID/
  - d. Replace PASSWORD with user's PASSWORD  
Type in  
C/PASSWORD/USER'S PASSWORD/
  - e. Replace all KOEUSER with user's KOE USER ID  
Type in  
C/KOEUSER/USER'S KOE USER ID/\*
  - f. Change data file name (optional)\*  
Type in  
C/FINDAT1/NEW FILE NAME/  
C/FINDAT/NEW FILE NAME/

(\*See Note, page 83)

```

OLD,FINDIR
/LIST
*IDENT PARAIS
*0 MAIN.2
    PROGRAM FINIT(TAPE4=TAPE4,TAPE8=TAPE8,OUTPUT,TAPE6=OUTPUT,
*0 MAIN.3,MAIN.4
    1TAPE9=TAPE9,TAPE11=TAPE11,TAPE12=TAPE12,
    2TAPE13=TAPE13,TAPE14=TAPE14,TAPE15=TAPE15)
*0 MAIN.6
CCC SAMPLE PROBLEM
*0 MAIN.8
C*****
*0 MAIN.14
C*****
*0 MAIN.13
C NEQT= TOTAL NO. OF SIM. LIN. EQS. = NNOD+NCS
C IKK= TOTAL NO. OF CASAS TO BE COMPUTED
C ISFT= TOTAL NO. OF SELECTD ELEVATION STATION WITH RESPECT TO NODES
C ISFTE= TOTAL NO. OF SELECTED ELEVATION STATION WITH RESPECT TO ELEMENTS
C XK= WAVE PERIOD
C SYSQ,STMP,AT,AF HAVE DIMENSION OF NEQT.
C X,Y,NOD HAVE DIMENSION OF NNOD.
C XJ,XY,XH,HD HAVE DIMENSION OF NCS.
C ANGL,SN HAVE DIMENSION OF NODR.
C DD,V,U,YC,NCON HAVE DIMENSION OF NELE.
C NR AND Z HAVE THE DIMENSION OF THE NO. OF THE NODAL POINTS IN EACH CELL
C NSP HAS THE DIMENSION OF IPST
C NSFE HAS THE DIMENSION OF IPSTE
C IPER HAS THE DIMENSION OF 5
C XK HAS THE DIMENSION OF IKK
C AF HAS THE DIMENSION OF ISFT+1
C SYSK HAS THE DIMENSION OF NLGLXNBANDX2+50
C SYTF AND FTEPF HAVE DIMENSION OF NLGLXNBAND+100
C NUMBLK=NEQT*NBBAND/IBLKLEN+1
C NLG = NEQT/NUMBLK
C NLGL = NEQT-(NUMBLK - 1)*NLG
C NSTMP = NLG+NLGL
*0 MAIN.18,MAIN.21
C
    PARAMETER(NNOD=35,NELE=48,NODR=9,NCS=7,ISFT=35,ISFTE=48)
    PARAMETER(NSYSK=1394,NSYTF=772,NSTMP=84)
    DIMENSION X(NNOD),Y(NNOD),NOD(NNOD),XJ(NCS),
    *XY(NCS),XH(NCS),DH(NCS),ANGL(NODR),SN(NODR),NSP(100),IPER(5)
    DIMENSION ID(20),NSFE(100)
    DIMENSION Z(3)
*0 MAIN.22,MAIN.24
    COMMON/L1/SYSK(NSYSK)
    COMMON/L2/SYSQ(NSTMP)
    COMMON/L3/STMP(NSTMP)
    COMMON/L4/DD(NELE)
    COMMON/L5/AT(NNOD+NCS)
    COMMON/L6/AF(NNOD+NCS)
    COMMON/L7/SYTF(NSYTF)
    COMMON/L9/U(NELE),V(NELE),YC(NELE)
    COMMON/L8/NCON(NELE,3)
    DIMENSION FTEPF(NSYTF)
*0 MAIN.25,MAIN.28
    DIMENSION VJ(100),VY(100)
    DIMENSION NR(3)
    DIMENSION AF(100)
*0 MAIN.32
*0 MAIN.35,MAIN.37

```

Figure 29. Program FINDIR, update correction file for program FINITE  
(Sheet 1 of 7)

```

      READ (8,2) ID
      *D MAIN.41
        READ(8,5435) NBAND,IPR,RR,ALPHA,DM,IBLKLEN
      5435 FORMAT(2I5,F10.2,F10.5,F10.2,1I6)
      *D MAIN.42
      *I MAIN.46
        WRITE(6,403) NUMBLK
      403 FORMAT(1X,'NUMBLK',I5)
      *D MAIN.48
        D1=1.
        READ(8,305) IFC,IFMAX,IDFC,IDCH,IBUGA,IBUGG,IBUGL,JDISP,
      1 ICIRC,NC
      305 FORMAT(10I5)
        IF(ICIRC.NE.1) GO TO 3010
      C FOR CIRCULAR REGION NCS2=(NCS+1)/2 = TOTAL NO. OF COEFF. IN RAD. DOMAIN
        NCS2=(NCS+1)/2
        NCK2=2*NCS2
        IF(NCK2.NE.NCS) GO TO 3010
        WRITE(6,877)
      877 FORMAT(1X,33HNCS MUST BE ODD FOR CIRCULAR GRID)
        STOP
      3010 IF(IPR.EQ.0) GO TO 876
      876 CONTINUE
      *D MAIN.54
        IF(NLG*NBAND.LE.NSYSK) GO TO 5432
      *D MAIN.58
        NNELE=NELE
        NNNOD=NNOD
        NNODR=NNODR
        NNCS=NCS
        WRITE(6,12) NNELE,NNNOD,NNODR,NNCS,REQT,ALPHA,DA2,DA4,RR,D1,DM
      *I MAIN.72
        WRITE(6,2010)
      *D MAIN.73
      *D MAIN.75
        WRITE(6,2014) NUMBLK,NLG,NLGL,IBLKLEN,IPR,NBAND
        IF(NLG.GE.NBAND) GO TO 878
        WRITE(6,879)
      879 FORMAT(1X,30HNLG MUST BE GREATER THAN NBAND)
        STOP
      878 CONTINUE
      *D MAIN.78
        READ(8,300) THIN,TDELT,IKK
      *D MAIN.80
        WRITE(6,300) THIN,TDELT,IKK
      *D MAIN.81
      300 FORMAT(2F10.2,I5)
      *I MAIN.82
        IF(IKK.EQ.1) GO TO 321
      *I MAIN.86
      321 CONTINUE
      *D MAIN.87,MAIN.89
        IF(ICIRC.EQ.1) DA2=2.*PAI/NNODR
        IF(ICIRC.EQ.1) DA4=DA2/2.
      *D MAIN.90,MAIN.93
        IF(IFC.EQ.0) GO TO 3000
        READ(8,306)(NSF(J),J=1,ISFT)
        READ(8,306)(NSPE(J),J=1,ISPT)
      C   LEVEL 2,U,V,YC
      C   LEVEL 2,NCON,DD,AF,AT
      *D MAIN.94
      306 FORMAT(14I5)
      *I MAIN.100
        T=XK(IK)
        G 32.2
        IF(IDISP.EQ.0) GO TO 77

```

Figure 29. (Sheet 2 of 7)

```

78 TM=G*WK*TANH(WK*DM)
   T1=SQRT(TM)
   T2=2.*FAI/T1
   T3=XK(IK)-T2
   T4=ABS(T3)
   IF(T4.LE.0.01) GO TO 76
   DK=-2.*FAI*T3/(XK(IK)*XK(IK)*SQRT(G*DM))
   WK=WK+DK
   GO TO 78
76 XR=.5*(1.+2.*WK*DM/SINH(2.*WK*DM))
   D1=(XR*4.*FAI*FAI)/(T*T*G*WK*WK)
   WRITE(6,74) D1
74 FORMAT(//,25X,44HDISPERSION INCLUDED. D1 REPLACED BY C*CG/G =,F10.
12)
77 CONTINUE
*I MAIN.101
73 FORMAT(//,25X,24H WAVE PERIOD IN SECONDS =,F10.2,24X,9H WAVE NO =,E
112.5,/)
*D MAIN.102,MAIN.103
*D MAIN.106
   1,NELE,NNOD,NODR,NCS,NEQT,NBAND,NCS2,DD,IDFC,DM,IDCH,DISP)
*D MAIN.112
   1,HLG,IDFC,IBUGA,DM,IDISF,T)
*D MAIN.118
   1,NELE,NNOD,NODR,NCS,NEQT,NBAND,NCS2,NODR1,VJ,VY,HLGL,IBUGG,ICIRC)
*D MAIN.124
   1,NELE,NNOD,NODR,NCS,NEQT,NBAND,NCS2,NODR1,IRUGL,ICIRC)
*D MAIN.131,MAIN.138
*D MAIN.145
   IF(ICIRC.NE.1) AF(I)=AF(I)/2.
*I MAIN.191
C   WRITE(6,37) (I,AF(I),AT(I),I-1,NNOD)
C   37 FORMAT(6(I5,2F7.2))
*D MAIN.197
   260 Z(L)=AF(N)
*I MAIN.212
   JP=1
*I MAIN.213
   JP=JP+2
*D MAIN.218,MAIN.219
   WRITE(6,25) J,AF(J),AT(J),J1,AF(J1),AT(J1)
501 JFP=JP+1
   AF(JFP)=AF(J)
   IF(II.GT.ISFT) GO TO 503
   AF(JFP)=AF(J1)
*D MAIN.221
503 WRITE(6,24) J,AF(J),AT(J)
*I MAIN.222
   IF(NC.EQ.0) GO TO 103
   WRITE(6,101)
101 FORMAT(4H [[C)
103 WRITE(6,201)
201 FORMAT(//)
   WRITE(6,200) (AF(II),II-1,ISFT)
200 FORMAT(13F6.2)
*D MAIN.223
502 CONTINUE
*D MAIN.224,MAIN.234
*D MAIN.240,MAIN.241
   WRITE(6,25) I,AF(I),AT(I),II,AF(II),AT(II)
*D MAIN.243
415 WRITE(6,24) I,AF(I),AT(I)
*D MAIN.245,MAIN.255
222 FORMAT(3(I5,1X,3E12.5,1X))
*D MAIN.257
   IF(NC.EQ.0) GO TO 104

```

Figure 29. (Sheet 3 of 7)

```

WRITE (6,102)
102 FORMAT(4H [[L)
104 IF(IPC.EQ.0) GO TO 99
*0 MAIN.278,MAIN.280
*0 MAIN.282,MAIN.285
24 FORMAT(1X,15,2E12.5)
25 FORMAT(1X,2(15,E12.5,2X,E12.5))
C IF(IPMAX.NE.0) CALL CPUNCH(NODPT,IPMAX,AF,U,V,NNOD,NELE,NEQT,XK,IK,
C 1NSP,ISPT,IPER,ID,IPC,NSPE,ISPE,IKT)
*0 INPT.3
1,NELE,NNOD,NODR,NCS,NEQT,NBAND,NCS2,DD,IDPC,DM,IDCH,IDTSP)
*I INPT.8
C LEVEL 2,NCON,DD
*0 INPT.16,INPT.37
READ(4,200) (X(I),I=1,NNOD)
READ(4,200) (Y(I),I=1,NNOD)
200 FORMAT(8F10.2)
C DO 1000 I=1,NNOD
C X(I)=X(I)*.1110
C Y(I)=Y(I)*.1110
C DO 647 I=1055,NNOD
C II=I-NODB1+1
C IF(I.LT.1100) ADD=(I-1055)*DA2+.5*DA2
C IF(I.GE.1100) ADD=(II-1)*DA2
C RS=140000.
C IF(I.LT.1100) RS=140000.
C X(I)=-RS*COS(ADD+ANGG)
C Y(I)=-RS*SIN(ADD+ANGG)
C 647 CONTINUE
101 FORMAT(3(5X,315))
READ(4,101) ((NCON(I,J),J=1,3),I=1,NELE)
C DO 83 I=1,NELE
C 83 DD(I)=6.*DD(I)
CALL GDEPTH(IDPC,DD,NNOD,NODB2,NELE,IDCH)
IF(IDCH.EQ.1) GO TO 430
GO TO 450
430 PRINT 316,(I,X(I),Y(I),I=1,NNOD)
DO 440 I=1,NELE
PRINT 420, I,(NCON(I,J),J=1,3)
440 CONTINUE
316 FORMAT(2(I10,2F10.2))
420 FORMAT(1X,6(15,1X,315))
450 IF(IDISP.GT.0) GO TO 70
IF(IDPC.NE.0) GO TO 400
*I INPT.38
DD(I)=DD(I)/DM
*0 INPT.44,INPT.48
70 CONTINUE
*0 INPT.49
416 FORMAT(4(4X,415))
*0 INPT.50
IF(IDCH.EQ.1) PRINT 416, (L,(NCON(L,J),J=1,3),L=1,NELE)
*I DEPTH.7
C LEVEL 2,DD
*I DEPTH.9
DO 10 I=1,NELE
10 DD(I)=0.25
*0 DEPTH.10,DEPTH.40
*0 DEPTH.45,DEPTH.46
1000 READ(4,980) (DD(I),I=1,NNOD)
980 FORMAT(8F10.2)
IF(IDCH.EQ.1)PRINT 2010, (DD(I),I=1,NNOD)
*0 DEPTH.47
*I BAND.4
C LEVEL 2,NCON
*0 ASBK.5

```

Figure 29. (Sheet 4 of 7)

```

      1,NLGG,IDPC,IBUG,DM,IDISP,T)
*0 ASBK.21
C      LEVEL 2,SYSK,SYSQ,ST,NCON,DD
*0 ASBK.73
C      IF(L.GE.1435.AND.L.LE.1571)D9=0.5
*0 ASBK.80
      CALL ELMK(X1,X2,X3,Y1,Y2,Y3,WK,D9,DIN,ELK,AREA,L,RELE3,DM,IDISP,T)
*0 ASBK.84
      1050 DO 20 I=1,3
*1 ASBK.106
      L4=IQ+9
*0 ASBK.113
      999 WRITE(6,777)
*0 GSPK.3
      1,RELE,NMOD,NODR,NCS,NEQT,REAND,NCS2,NODR1,VJ,VY,NLGG,IBUG,ICIRC)
*0 GSPK.14
*0 GSPK.12
      1,ANGL(NODR)
*1 GSPK.22
      CALL BESSY(WR,0,NCS,VJ,VY)
      NDUM=NCS
      IF(ICIRC.EQ.1) NDUM=NCS2
      IF(IBUG.EQ.0) GO TO 13
      WRITE(6,21)
      21 FORMAT(//,1X,'XJ=',10X,'XY=')
*0 GSPK.23
      13 DO 12 I=1,NDUM
*0 GSPK.23,GSPK.26
*1 GSPK.31
      IF(IBUG.EQ.0) GO TO 14
      WRITE(6,22)
      22 FORMAT(//,1X,'XH=',10X,'DH=')
*0 GSPK.32
      14 DO 15 I=1,NDUM
*0 GSPK.43
      20 FORMAT(9H GSPK BY=,4E15.8)
*0 GSPK.50
      DO 38 I=1,NCS
      III=I/2+1
*1 GSPK.55
      ICE=I
      IF(ICIRC.EQ.1) ICE=III
      IF(ICIRC.EQ.1) CX=2.*CX
*0 GSPK.56
      SYSK(II,1)=SYSK(II,1)+CX*KKHF*XH(ICE)*DH(ICE)
*1 GSPK.60
      CT=1.
      IF(ICIRC.EQ.1) CT=2.
      ND=NODR1
      IF(ICIRC.EQ.1) ND=NODR
*0 GSPK.61
      DO 40 I=1,ND
*1 GSPK.69
      IF(I1.EQ.0.AND.ICIRC.EQ.1) I1=NODR
*1 GSPK.71
      IF(ICIRC.EQ.1) GO TO 935
      GO TO 936
      935 J2=J/2
      J1=J2+1
      A1=ANGL(I)*J2
      A2=ANGL(I1)*J2
      936 CONTINUE
*0 GSPK.74
      TM=CT*HKLADH(1)
      IF(ICIRC.EQ.1) GO TO 46
*1 GSPK.77

```

Figure 29. (Sheet 5 of 7)

```

      IF (ICIRC .EQ. 1) GO TO 937
      GO TO 938
937  IF (MOD(J,2).EQ.1) GO TO 44
      TM=HKL*DH(J1)*(COS(A2)+COS(A1))
      GO TO 46
938  CONTINUE
*I  GSPK.88
      GO TO 46
      44  TM=HKL*DH(J1)*(SIN(A2)+SIN(A1))
*D  GSPK.91
*D  GSPK.97
C    WRITE(6,1018) (SYSK(I,1),SYSK(I,2),I=1,NLGG)
*D  GSPK.98
C1018  FORMAT(1X,4G14.5)
*D  GSPK.100
      2000  WRITE(6,999)
*D  GSPK.103
      1551  WRITE(6,1520) NLLL
*D  LOAD.3
      1,NELS,NNOD,NODR,NCS,NEQT,NBAND,NCS2,NODR1,IRUG,ICIRC)
*D  LOAD.9
      DIMENSION SH(NODR),SYSQ(NEQT),DH(NCS),XJ(NCS),ANGL(NODR)
*D  LOAD.10
*I  LOAD.15
      NDUM=NODR1
      IF(ICIRC.EQ.1) NDUM=NODR
*D  LOAD.16
      DO 12 I=1,NDUM
*I  LOAD.23
      IF(ICIRC.EQ.1) DUM2=(0.0,0.0)
*I  LOAD.31
      IF(ICIRC.EQ.1) GO TO 52
*I  LOAD.33
      52  CONTINUE
*I  LOAD.34
      IF(II.EQ.0.AND.ICIRC.EQ.1) II=NODR
*I  LOAD.49
      IF(ICIRC.EQ.1) II=I/2
      IJ=II+1
*I  LOAD.51
      IF(ICIRC.EQ.1) GO TO 555
      GO TO 556
      555  IF(I.EQ.1) GO TO 557
      IF(MOD(I,2).EQ.1) GO TO 18
      TM=CH*XJ(IJ)*DH(IJ)*COS(AI)
      GO TO 20
      557  TM=XJ(1)*DH(1)
      GO TO 20
      18  TM=CH*XJ(IJ)*DH(IJ)*SIN(AI)
      GO TO 20
      556  CONTINUE
*I  LOAD.32
      20  CONTINUE
*D  ELMT.3
      1NELE3,DH,DISP,T)
*I  ELMT.25
C    WRITE(6,500) X1,X2,X3,Y1,Y2,Y3
*I  ELMT.30
      XN3=WK/SQRT(D)
      IF(IDISP.NE.1) GO TO 300
      XK1=XK1*SQRT(DH)
      PI=3.1416
      150  TM=G*XK1*TANH(XK1*H)
      T1=SQRT(TM)
      T2=2.*PI/T1
      T3=T-T2

```

Figure 29. (Sheet 6 of 7)

```

      T4=ABS(T-T2)
      IF(T4.LE..01) GO TO 200
      DK=-2.*PI*T3/(T*T*SQRT(G*D))
      XK1=XK1+DK
      GO TO 150
200  CONTINUE
      XN=.5*(1.+2.*XK1 *D/SINH(2.*XK1*D))
      XD=(XN*4.*PI*PI)/(T*T*G*XK1*XK1)
      GO TO 400
300  XD=D
400  CONTINUE
*D  ELMT,31,ELMT,33
      WKA=DIN*XK1*XK1*AREA/12.
      SAV=D
      D=XD
*D  ELMT,43
      D=SAV
*I  BESJ,11
      FN=N
*D  BESJ,80
      GAM3=-GAM3*GAM2
*D  BESJ,38
      5 F(I)=CONST*(FLI+FNU)*F(I+1)-F(I+2)
*D  BESJ,76
      21 F(L)=CONST*FRAC*F(L-1)-F(L-2)
*D  BESJ,202
      114 F(I)=CONST*(FNU+FLI)*F(I-1)-F(I-2)
*D  GAMA,53,GAMA,56
      XFT=EXP(TEM)/XFT
      ANS=XFT
      GO TO 6000
4000 SUM=0.0
*I  BANDS,5
      DIMENSION Q(100,100),R(100,100),HL(100),HL(100)
*D  BANDS,7
*D  BANDS,44
      IF(REAL(A(N,L))) 230,275,230
*D  BANDS,62
      F(N,K)=A(N,K)
      127 CONTINUE
*D  BANDS,74
      A(NM,NB)=B(N)
      450 CONTINUE
*D  BANDS,85
      A(N,K)=F(N,K)
      136 CONTINUE
*D  BANDS,93
      D(K)=A(NM,NB)
      600 CONTINUE
*D  BANDS,96
      444 WRITE(6,666)N
*D  BANDS,101,BANDS,102
      999 WRITE(6,998) A(N,1),N,NB
      998 FORMAT(13H DIAG TROUBLE ,GX,2G13.5,2I5)
*D  FILL,17
      WRITE(6,666)N
*D  FILL,5
      DIMENSION Q(100,100),R(100,100),HL(100),HL(100)
*D  ECWR,4
*D  ECWR,7,ECWR,9
      BUFFER OUT(L1,0)(S(1),S(L2))
      IF(UNIT(L1))10,20,30
      30 WRITE(6,40)
      40 FORMAT(1X,'PARITY ERROR')
      20 IERR=1
      10 RETURN
*D  ECRD,4
*D  ECRD,7,ECRD,9
      BUFFER IN(L1,0)(S(1),S(L2))
      IF (UNIT(L1))10,20,30
      30 WRITE(6,40)
      40 FORMAT(1X,'PARITY ERROR')
      20 IERD=1
      10 RETURN

```

Figure 29. (Sheet 7 of 7)



(\*Note: File FINDAT1 contains Data Set No. 1 through Data Set No. 3. File FINDAT contains Data Set No. 4 through Data Set No. 7. File FINDAT can be obtained at the completion of the run of the plotting program FNGRID. If that is the case, the new file name replacing FINDAT should correspond with the file name that was used to save TAPE10 in the procedure file PLOTf.)

- g. Replace file FINI with the edited version  
Type in  
E,,RL
- h. To execute file FINI  
Type in  
SUBMIT,FINI
- i. To check job status  
Type in  
LINK,ENQUIRE,PD=MODD,PT=HHMM  
(PD=MODD, where MO is the month from 01 to 12, and DD is the date from 01 to 31. PT=HHMM, where HH is the hour from 01 to 24, and MM is the minute from 01 to 60. Example:  
To generate status information for a job received since 9:00 a.m. on 31 May, type in  
LINK,ENQUIRE,PD=0531,PT=0900  
The last three characters of the run JOB NAME will not stay the same as in initiated job names. The system assigns different names at different stages that transmit a job from KOE to CYBER 205, or vice versa. If the job output is available at KOE, then continue to the next step.)
- j. To execute "QLIST"  
Type in  
OLD,QLIST  
BEGIN,,QLIST,XXX,LSV,DSV  
(where XXX are the last three characters of the job name that appeared in the statement "JOB NAME IS IN USER QGET QUEUE."  
LSV causes the output to be saved with file name HASHXXX.  
DSV causes the dayfile to be saved with file name DAYXXX.)
- k. To list output and dayfile on the user's terminal  
Type in  
OLD,FILE NAME  
LIST
- l. To direct output and dayfile to a fast printer at COPE terminal  
Type in  
GET,LFN=FILE NAME  
ROUTE,LFN,DC=PR,UN=COPE USER'S ID  
(where LFN is the local file name, and FILE NAME is the permanent file name)

#### A Sample Application

55. In this sample application to demonstrate the execution of program

FINITE on the CYBER 205 COMPUTER SYSTEM, the values of the parameters in the parameter statements stay unchanged.

- a. Obtain the source file FINITE  
Type in  
GET,FINITE/UN=CEROMO  
/SAVE,FINITE
- b. Establish AFFILE "AF205" on CYBER 205

1. To execute file AFJCL

```

GET,AFJCL/UN=CEROMO
/SAVE,AFJCL
/OLD,AFJCL
/XEDIT
XEDIT 3.1.00
?? C/205USER/052010/
USER(U=052010,PA-PASSWORD)
?? C/PASSWORD/IODINE/*
USER(U=052010,PA-IODINE)
--EOR--
USER(KOEUSER,IODINE,KOE)
END OF FILE
?? T
?? C/KOEUSER/CEROMB/*
CHARGE(CEROEGC,CEROMB)
--EOR--
USER(CEROMB,IODINE,KOE)
CHARGE(CEROEGC,CEROMB)
END OF FILE
?? E,,RL
AFJCL    REPLACED
AFJCL    IS A LOCAL FILE
AEB ,    0.257UNTS.
/GET,ADYJOB/UN=CATHIDC
/BEGIN,,ADYJOB,AFJCL
ALL DONE.  USER JOB NAME IS COE429
$REVERT.
/

```

2. Use "LINK,ENQUIRE" to check job status

```

LINK,ENQUIRE,JN=COE429
STATUS FOR CEROMB /KOE

```

DATE TIME	USER	SYSTEM	FILE	FILE
MMDD HHMM	JOB NAME	JOB NAME	TYPE	STATUS
0522 1020	COE429	AJZZ305	NO	ROUTING INITIATED TO KAA
0522 1244	COE429	SENDLOT	TO	ARRIVED AT ADY
0522 1245	COE429	AUUAL00	NO	ARRIVED AT KAA
0522 1245	COE429	AUUAL00	TO	AUUAL00 LINKING TO ADY
0522 1246	COE429	AJZZL0T	WT	OUTPUT AVAILABLE AT KOE/T

LINK COMPLETE.

### 3. Use "QLIST" to access the output

```

OLD,QLIST
/REGIN,,QLIST,LQT
11.44.47 RESOURCE(JCAT=P6,TL=200)
11.44.49 CHARGE, CER0EGC,CEROMB
11.44.49 ALL DONE
11.44.49 TV,10+.
11.44.49 PURGE(AF205)
11.44.50 ALL DONE
11.44.50 TV,1+.
11.44.50 COPY,INPUT,AF205.
11.44.51      9 WORDS OF FILE  INPUT      COPIED TO FILE AF205
11.44.51 ALL DONE
11.44.51 DEFINE,AF205.
11.44.51 EXISTING LOCAL FILE MADE PERMANENT
11.44.51 ALL DONE
11.44.51      CHARGE,CER0EGC ,CEROMB      3.982 SBUS
11.44.51 SYSTEM BILLING UNITS (SBU)      3.982
11.44.51 USER CPU TIME (SECS)            .194
11.44.51 SYSTEM CPU TIME (SECS)          .693
11.44.51 USER MEMORY USAGE (PAGE*SECS)   18.731
11.44.51 USER AVERAGE WORKING SET SIZE (PAGES) 96
11.44.51 NUMBER OF VIRTUAL SYSTEM REQUESTS 235
11.44.51 NUMBER OF SMALL PAGE FAULTS      73
11.44.51 NUMBER OF DISK I/O REQUESTS      11
11.44.51 NUMBER OF DISK SECTORS TRANSFERRED 11
11.44.51 $$COMPLETE$$
END OF FILE
/

```

#### c. Establish the file "QLIST"

```

GET,QLIST/UN=CEROMB
/SAVE,QLIST
/OLD,QLIST
/XEDIT
XEDIT 3.1.00
?? C/HASH/AJZZ/
.PROC,QLIST,FID,LSV=N/Y,DSV=N/Y,DSP=N/Y,UID=AJZZ,UN=USERNUM,AUN=CHENDDC,
?? C/USERNUM/CEROMB/
.PROC,QLIST,FID,LSV=N/Y,DSV=N/Y,DSP=N/Y,UID=AJZZ,UN=CEROMB,AUN=CHENDDC,
?? C/HEADER1/LUCYCHOU/
H1=LUCYCHOU,H2=HEADER2,H3=HEADER3.
?? C/HEADER2/CERC/
H1=LUCYCHOU,H2=CERC,H3=HEADER3.
?? C/HEADER3/WES/
H1=LUCYCHOU,H2=CERC,H3=WES.
?? E,,RL
QLIST REPLACED -
QLIST IS A LOCAL FILE
AEB ,      0.254UNTS.
/

```

d. Create an Update Library

```
GET,FINUP1/UN=CEROM0
/SAVE,FINUP1
/BEGIN,RUNF,FINUP1
15.56.41. SUBMIT COMPLETE.  JOBNAME IS AJZZFOT
$REVERT.CCL
/ENQUIRE,JN=FOT
AJZZFOT  NOT FOUND.
/OLD,DAY1
/LIST
15.56.41.FINIJOB,CM320000,P6.
15.56.41.ABF , INPUT , 0.002KIDDB,01.
15.56.41.USER,CEROM8,,KOE.
15.56.41.ARG , P6.
15.56.42.CHARGE,CEROEGC,CEROM8.
15.56.43.GET,FINITE.
15.56.44.UPDATE(I=FINITE,N=LIBLC)
15.56.44.UPDATE CREATION RUN
15.56.44.CREATING NEW PROGRAM LIBRARY
15.56.46. UPDATE COMPLETE.
15.56.46.SAVE,LIBLC=LIBLC.
15.56.47.DAYFILE,DAY1.
/
```

e. Establish an Update Correction File "FINDIR". (In the sample run, file FINDIR is used without change.)

```
Type in
GET,FINDIR/UN=CEROM0
/SAVE,FINDIR
/
```

f. To execute program FINITE with Update Correction file FINDIR  
1. Execute file FINI

```
GET,FINI/UN=CEROM0
/SAVE,FINI
/OLD,FINI
/XEDIT
XEDIT 3.1.00
?? C/205USER/052010/
USER(U-052010,PA=PASSWORD)ADY
?? C/PASSWORD/IODINE/
USER(U-052010,PA=IODINE)ADY
?? C/LOEUSER/CEROM8/
CHARGE(CEROEGC,CEROM8)
GETKOE,CONF/ID=C6,UN=CEROM8.
LINK,REPLACE(LIST:LIST205/UN=CEROM8,FM=KOE,DD=C6,AF=AF205)
LINK,REPLACE(FNNAP=MAP205/UN=CEROM8,FM=KOE,DD=C6,AF=AF205)
LINK,REPLACE(LIST:LIST205/UN=CEROM8,FM=KOE,DD=C6,AF=AF205)
LINK,REPLACE(FNNAP=MAP205/UN=CEROM8,FM=KOE,DD=C6,AF=AF205)
END OF FILE
?? E,,RL
FINI      REPLACED
FINI      IS A LOCAL FILE
ABF ,      0.255UNTS.
/SUBMIT,FINI
14.24.02. SUBMIT COMPLETE.  JOBNAME IS AJZZWQA
/
```

2. Check job status

LINK,ENQUIRE,PD=0531,PT=0100  
STATUS FOR CEROMB /KOE

DATE	TIME	USER	SYSTEM	FILE	FILE
MMDD	HHMM	JOB NAME	JOB NAME	TYPE	STATUS
0531	1424	COE555	AJZZWQA	NO	ROUTING INITIATED TO KAA
0531	1433	COE555	LUCYGIJ	TO	ARRIVED AT ADY
0531	1433	COE555	AUUAGIH	NO	ARRIVED AT KAA
0531	1434	COE555	AUUAGIH	TO	AUUAGIH LINKING TO ADY
0531	1439	COE555	AJZZGIJ	WT	OUTPUT AVAILABLE AT KOE/T

LINK COMPLETE.

3. To retrieve job output and save it as a permanent file

Type in  
OLD,QLIST  
/BEGIN,,QLIST,GIJ,LSV,DSV

4. To route the output to the remote COPE terminal

Type in  
GET,OUTLUCY=AJZZGIJ  
/ROUTE,OUTLUCY,DC=PR,UN=CERORC  
The system will respond with  
ROUTE COMPLETE

5. A listing of the sample application output from the COPE terminal includes the following:

SAINT-PIERRE FORLEH

TOTAL NO. OF ELEMENTS	48	TOTAL NO. OF NODES	35	TOTAL NO. OF SOURCES	9	FIRST ELEMENT W.R.I. SOURCES
TOTAL NO. OF SIM. LINEAR EQS	42	WAVE ANGLE OF INCIDENCE	4.7125	THICKNESS IN ANG. DEGREES	.3527	.1532
OUTTEST EXTEND OF FINITE DOMAIN		12.00	NO. OF OUTER RING	1.00	AVER. INFLUENCE OF SEMIINFINITE	1.33

INPUT DATA CHECK--ECHO PRINT

[illegible]

WAVE PERIOD IN SECONDS	141.76
WAVE NO	.78108E-02

000  
PAGE WIDTH 16  
END PAGE WIDTH W.P.T. ELEMENT 15  
000  
END PAGE WIDTH W.P.T. SOURCE + PAPER 16  
000

[illegible]

XH=

001

GSFK FY .99760487E+00 --.15760292E+01 --.4681361E-01 .48804369E+01  
 GSFK FY .4681361E-01 --.68609307E+01 .49833375E+00 .12166010E+02  
 GSFK FY .10973347E-02 --.14524319E+03 .23376254E-01 .59725021E+04  
 GSFK FY .1711533E-04 --.51916854E+04 .54836184E-03 .17007651E+03  
 GSFK FY .2006028E-05 --.39620639E+05 .46719772E-05 .16902182E+08  
 GSFK FY .1983244E-08 --.33310563E+03 .10041631E-05 .13032152E+10  
 GSFK FY .1471027E-10 --.36068268E+10 .51157400E-07 .23855190E+12

GSFL COMPLETE

ELEVATION AND VELOCITY FOR SELECTED ELEVATION POINTS

1	.12310E+01	.18324E-01	2	.12310E+01	.18324E-01
3	.12310E+01	.18324E-01	4	.12278E+01	.18324E-01
5	.12278E+01	.18324E-01	6	.12214E+01	.18324E-01
7	.12214E+01	.18324E-01	8	.12214E+01	.18324E-01
9	.1226E+01	.18324E-01	10	.12084E+01	.18324E-01
11	.11927E+01	.18324E-01	12	.11927E+01	.18324E-01
13	.11927E+01	.18324E-01	14	.11707E+01	.18324E-01
15	.11707E+01	.18324E-01	16	.11455E+01	.18324E-01
17	.11455E+01	.18324E-01	18	.11455E+01	.18324E-01
19	.11455E+01	.18324E-01	20	.11455E+01	.18324E-01
21	.10946E+01	.18324E-01	22	.10946E+01	.18324E-01
23	.10946E+01	.18324E-01	24	.10946E+01	.18324E-01
25	.10946E+01	.18324E-01	26	.10946E+01	.18324E-01
27	.10946E+01	.18324E-01	28	.10946E+01	.18324E-01
29	.10946E+01	.18324E-01	30	.10946E+01	.18324E-01
31	.10946E+01	.18324E-01	32	.10946E+01	.18324E-01
33	.10946E+01	.18324E-01	34	.10946E+01	.18324E-01
35	.10946E+01	.18324E-01	36	.10946E+01	.18324E-01

1.23	1.23	1.23	1.23	1.23	1.23	1.21	1.19	1.19	1.19
1.17	1.17	1.17	1.17	1.17	1.17	1.07	1.07	1.07	1.07
1.03	1.03	1.03	1.03	1.03	1.03	1.04	1.04	1.04	1.04

SOURCE POINTS

37	.10674E-05	.13280E+01
38	.10395E-08	.10944E+01
39	.10312E-12	.10233E+01
40	.10373E+01	

# VELOCITY FOR SELECTED VELOCITY STATIONS(ELEMENTS)

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4	.78724E-05	.11611E+01	.11611E+01	5	.29004E+00	.87108E+00	.87108E+00	6	.29004E+00	.87108E+00	.87108E+00	.87108E+00
7	.78724E-05	.11611E+01	.11611E+01	8	.29004E+00	.87108E+00	.87108E+00	9	.78724E-05	.23111E+01	.23111E+01	.23111E+01
10	.78724E-05	.23111E+01	.23111E+01	11	.28549E+00	.25996E+01	.25996E+01	12	.44374E-04	.28852E+01	.28852E+01	.28852E+01
13	.28552E+00	.25996E+01	.25996E+01	14	.28549E+00	.25996E+01	.25996E+01	15	.44374E-04	.28852E+01	.28852E+01	.28852E+01
16	.28552E+00	.25996E+01	.25996E+01	17	.44374E-04	.25996E+01	.25996E+01	18	.44374E-04	.28852E+01	.28852E+01	.28852E+01
19	.27654E+00	.42875E+01	.42875E+01	20	.11463E-04	.45641E+01	.45641E+01	21	.27654E+00	.42875E+01	.42875E+01	.42875E+01
22	.27654E+00	.42875E+01	.42875E+01	23	.52785E-03	.56435E+01	.56435E+01	24	.27654E+00	.42875E+01	.42875E+01	.42875E+01
25	.11463E-04	.56435E+01	.56435E+01	26	.52785E-03	.56435E+01	.56435E+01	27	.10953E+01	.67203E+01	.67203E+01	.67203E+01
28	.11463E-04	.56435E+01	.56435E+01	29	.52785E-03	.56435E+01	.56435E+01	30	.57051E+00	.50762E+01	.50762E+01	.50762E+01
31	.16670E+01	.61728E+01	.61728E+01	32	.10970E+01	.67437E+01	.67437E+01	33	.62806E+01	.19785E+01	.19785E+01	.19785E+01
34	.16670E+01	.61728E+01	.61728E+01	35	.16670E+01	.67437E+01	.67437E+01	36	.62806E+01	.19785E+01	.19785E+01	.19785E+01
37	.25926E+01	.46665E+01	.46665E+01	38	.69743E-02	.51087E+01	.51087E+01	39	.25926E+01	.46665E+01	.46665E+01	.46665E+01
40	.25926E+01	.46665E+01	.46665E+01	41	.69743E-02	.51087E+01	.51087E+01	42	.25926E+01	.46665E+01	.46665E+01	.46665E+01
43	.17948E+01	.37274E+01	.37274E+01	44	.38340E+00	.38471E+01	.38471E+01	45	.38340E+00	.38471E+01	.38471E+01	.38471E+01
46	.18235E+01	.37133E+01	.37133E+01	47	.48914E+00	.36902E+01	.36902E+01	48	.48914E+00	.36902E+01	.36902E+01	.36902E+01

135 STUP

1 13.28.40 K592C

V592C

052010

REL21R

I

05/31/84

LUCYJ

13.28.40 RESOURCE(JCAT-F6,TL=100)

13.28.44 CHARGE, CEROGC,CEROMB

13.28.44 ALL DONE

13.28.44 ATTACH,LINKPOOL.

13.28.45 POOL LINKPOOL ATTACHED

13.28.45 ALL DONE

13.28.45 TV,10+

13.28.45 \*\*\*

13.28.45 \*\*\*GETADE,CONF/BD:G6,UN-CEROMB.

13.28.45 \*\*\*

13.28.45 MELINK(COFF,ST KAA:DD-C6,

13.28.45 JCS-\*\*\*\*\*

13.28.45 \*\*\*\*\*

13.28.46 WAITING FOR CONNECTED STATUS.

13.28.52

PTFS - USER(COEAPFL,)

13.28.52

PTFS - ATTACH(COE556/NA)

13.28.52

PTFS - FF REQUEST COMPLETE.

13.28.56

ALL DONE

13.28.56 \*\*\*GETADE(TAFB-FIRDA1)

13.28.56 \*\*\*

13.28.56 MELINK(TAFB,ST KAA:DD-C6,

13.28.56 JCS-\*\*\*\*\*

13.28.56 \*\*\*\*\*

13.28.57 WAITING FOR CONNECTED STATUS.

13.29.04

PTFS - USER(COEAPFL,)

13.29.04

PTFS - ATTACH(COE557/NA)

13.29.04

PTFS - FF REQUEST COMPLETE.

13.29.05

ALL DONE



```

13.29.06 ***
13.29.06 ***GETROE(TAPE4:FINOUT)
13.29.06 ***
13.29.06 HFLINK(TAPE4,ST:KAG,DD=C6,
13.29.06 JCS:*****),
13.29.06 "*****")
13.29.07 WAITING FOR CONNECTED STATUS.
13.29.14
13.29.14 FTFS - USER(COEAPFL,)
13.29.14
13.29.14 FTFS - ATTACH(COESS3/NA)
13.29.14
13.29.16 FTFS - PF REQUEST COMPLETE.
13.29.17 ALL DONE
13.29.17 FORTRAN(I COMPF,L=LIST)
13.29.18 FORTRAN 2.1.5 CYCLE L592C      BUILT 05/01/84 16:21
13.29.18 COMPILING FINIT
13.29.24 NO ERRORS
13.29.24 COMPILING CPUNCH
13.29.24 NO ERRORS
13.29.24 COMPILING INPUT2
13.29.24 NO ERRORS
13.29.24 COMPILING GUEPTH
13.29.24 NO ERRORS
13.29.24 COMPILING HAND
13.29.24 NO ERRORS
13.29.24 COMPILING ASEHKK
13.29.24 NO ERRORS
13.29.24 COMPILING GSPK
13.29.25 NO ERRORS
13.29.25 FILE BINARY      EXTENDED, NEW LENGTH =      32
13.29.25 COMPILING LOAD
13.29.25 NO ERRORS
13.29.25 COMPILING ELMK
13.29.25 NO ERRORS
13.29.25 COMPILING BESSY
13.29.25 NO ERRORS
13.29.25 COMPILING GAMMA
13.29.25 NO ERRORS
13.29.25 COMPILING BESSJ
13.29.26 NO ERRORS
13.29.26 COMPILING BANSOL
13.29.26 NO ERRORS
13.29.26 COMPILING FILL
13.29.26 NO ERRORS
13.29.26 COMPILING ECWR
13.29.26 NO ERRORS
13.29.26 COMPILING ECKD
13.29.26 NO ERRORS
13.29.26 1.944 SECONDS COMPILATION TIME
13.29.26 ALL DONE
13.29.26 LOAD,L FINMF.
13.29.27 LOAD R2.1 CYCLE L592C
13.29.37 ALL DONE
13.29.37 GO(TAPE4 OUTPUT)
13.29.41 *1 STOP **
13.29.41 ALL DONE
13.29.41 LINK,REPLACE(LIST LIST20G/UN=CEROMB,FH=KOF,DD=C6,AF=AF205)
13.29.41 LINK PHASE II VERSION LLINK50 BUILT 05/01/84      14.47.59

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13.29.44 REPLACE(LIST205/UN CEROMB.
13.29.44 L3882,PS. NOE JOB LLINK50 3882
13.29.51 WAITING FOR CONNECTED STATUS.
13.30.03 TRANSFER ABORTED
13.30.10 ALL DONE
13.30.10 LINK,REPLACE(FRMHF:NAF205/UN-CEROMB,FM NOF,DD C6,AF AF205)
13.30.11 LINK PHASE II VERSION LLINK50 BUILT 05/01/84 14.47.59
13.30.11 REPLACE(NAF205/UN CEROMB.
13.30.12 L3883,PS. NOE JOB LLINK50 3883
13.30.18 WAITING FOR CONNECTED STATUS.
13.30.31 TRANSFER ABORTED
13.30.36 ALL DONE
13.30.36 HFLINK(NULL,ST KAA,DD=C6,
13.30.36 JCS-*****',
13.30.36 '*****')
13.30.40 WAITING FOR CONNECTED STATUS.
13.30.49
13.30.49 FTFS - USER(COEAFPL,)
13.30.49
13.30.49 FTFS - PURGE(COE558/NA)
13.30.49
13.30.49 FTFS - PF REQUEST COMPLETE.
13.30.50 ALL DONE
13.30.50 HFLINK(NULL,ST KAA,DD=C6,
13.30.50 JCS-*****',
13.30.50 '*****')
13.30.52 WAITING FOR CONNECTED STATUS.
13.30.58
13.30.58 FTFS - USER(COEAFPL,)
13.30.58
13.30.58 FTFS - PURGE(COE557/NA)
13.30.58
13.30.58 FTFS - PF REQUEST COMPLETE.
13.31.00 ALL DONE
13.31.00 HFLINK(NULL,ST KAA,DD=C6,
13.31.00 JCS-*****',
13.31.00 '*****')
13.31.01 WAITING FOR CONNECTED STATUS.
13.31.08
13.31.08 FTFS - USER(COEAFPL,)
13.31.08
13.31.08 FTFS - PURGE(COE556/NA)
13.31.08
13.31.08 FTFS - PF REQUEST COMPLETE.
13.31.09 ALL DONE
13.31.09 CHARGE,CEROEGC,CEROMB 71.367 SHUS
13.31.09 SYSTEM BILLING UNITS (SBU) 71.367
13.31.09 USER CPU TIME (SFCS) 7.632
13.31.09 SYSTEM CPU TIME (SECS) 5.233
13.31.09 USER MEMORY USAGE (PAGE*SECS) 1742.860
13.31.09 USER AVERAGE WORKING SET SIZE (PAGES) 228
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13.31.09 NUMBER OF SMALL PAGE FAULTS 850
13.31.09 NUMBER OF DISK I/O REQUESTS 29.
13.31.09 NUMBER OF DISK SECTORS TRANSFERRED 629
13.31.10 %%COMPLETE%%

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AD-A149 467

EROSION CONTROL OF SCOUR DURING CONSTRUCTION REPORT 6  
FINITE - A NUMERICA. (U) ARMY ENGINEER WATERWAYS  
EXPERIMENT STATION VICKSBURG MS HYDRA.

2/2

UNCLASSIFIED

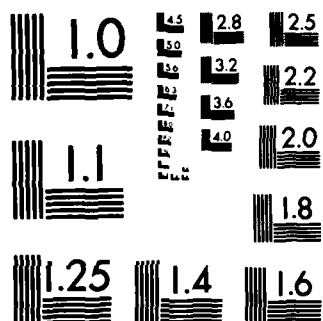
J R HOUSTON ET AL. SEP 84 WES/TR/HL-80-3-6 F/G 13/2

NL

END

FILMED

DTIC



MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

# 6. Listing of Data File FINDAT1

OLD,FINDAT1

/LIST

SAMPLE PROBLEM

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141.76		0.00	1											
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15	16	17	18	19	20	21	22	23	24	25	26	27	28	
29	30	31	32	33	34	35								
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15	16	17	18	19	20	21	22	23	24	25	26	27	28	
29	30	31	32	33	34	35	36	37	38	39	40	41	42	
43	44	45	46	47	48									

# 7. Listing of Data File FINDAT

OLD,FINDAT

LIST

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0.00	8.00	-4.00	4.00	-8.00	0.00	8.00	-4.00
4.00	0.00	12.00	11.00	8.50	4.60	0.00	-4.60
-8.50	-11.10	-12.00					
-32.00	-32.00	-32.00	-28.00	-28.00	-24.00	-24.00	-24.00
-20.00	-20.00	-16.00	-16.00	-16.00	-12.00	-12.00	-8.00
-8.00	-8.00	-4.00	-4.00	0.00	0.00	0.00	4.00
4.00	8.00	0.00	4.60	8.50	11.10	12.00	11.10
8.50	4.60	0.00					
1	2	4	2	3	5	1	4
4	7	6	2	7	4	2	5
5	8	7	3	8	5	6	7
7	8	10	4	9	11	9	12
7	12	9	7	10	12	10	13
6	13	10	11	12	14	12	13
11	14	16	14	17	16	12	17
12	15	17	15	18	17	13	18
16	17	19	17	18	20	16	19
19	22	21	17	22	19	17	20
20	23	22	18	23	20	35	21
21	22	24	22	23	25	23	27
21	24	34	22	25	24	23	28
34	24	33	24	25	26	25	28
24	32	33	24	26	32	25	30
25	29	30	26	31	32	26	30
.25	.25	.25	.25	.25	.25	.25	.25
.25	.25	.25	.25	.25	.25	.25	.25
.25	.25	.25	.25	.25	.25	.25	.25
.25	.25	.25	.25	.25	.25	.25	.25
.25	.25	.25	.25	.25	.25	.25	.25

## PART V: SUMMARY

56. A two-dimensional finite element numerical simulation model (FINITE) was developed that calculates wave heights under combined refraction and diffraction of both long and short waves approaching structures from any arbitrary direction. The wave equation solved governs the propagation of periodic, small amplitude surface gravity waves over a variable depth seabed of mild slope. The efficient formulation of the model permits the solution of large problems with relatively small time and memory storage requirements. A computational scheme is employed that allows the solution of practical problems that typically require large computational grids.

57. Although the model solves an equation that is strictly valid only for mild bathymetric variations, the model can provide reasonable answers for problems where there are rapid depth variations (at much lower cost than required by three-dimensional models that are appropriate for problems involving rapid depth variations). Comparisons are presented between the finite element model calculations and an analytical solution, a two-dimensional numerical solution, a three-dimensional numerical solution, and measurements from laboratory studies. Because the finite element FINITE does not provide a mechanism for energy dissipation, energy loss through wave breaking can be simulated only by permitting waves to propagate out of the computational region. The program documentation, user guide, and sample problem output are provided.

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# APPENDIX A: NOTATION

$a$	Wave amplitude, ft
$A$	Numerical computational region, dimensionless
$A$	Wave amplitude, ft
$A_I$	Incident wave amplitude, ft
$B$	Numerical computational region, dimensionless
$c$	Wave phase velocity $(g/k \tanh kh)^{1/2}$ , ft/sec
$c_g$	Wave group velocity $(1/2c(1 + G))$ , ft/sec
$F(\phi)$	Mathematical functional, dimensionless
$g$	Gravitational constant, 32.174, ft/sec <sup>2</sup>
$G$	Computational parameter $(2 k h / \sinh 2 kh)$ , ft/sec
$h$	Still-water depth, ft
$H_n$	Hankel function of the first kind, dimensionless
$i$	$(-1)^{1/2}$ , dimensionless
$k$	Wave number, $2\pi/L$ , 1/ft
$k_o$	Incident wave number, $2\pi/L_o$ , ft
$K$	Symmetric complex coefficient matrix, dimensionless
$L$	Arbitrary wavelength, ft
$L_o$	Incident wavelength, ft
$n$	Unit normal, dimensionless
$n_A$	Unit normal to the boundary separating computational regions $A$ and $B$ , dimensionless
$N$	Number of node points in the finite element discretization, dimensionless
$r$	Radial variables, ft
$T$	Wave period, sec
$\bar{u}$	Two-dimensional velocity vector, ft/sec
$\alpha_n$	Constant coefficients in Hankel functions, dimensionless
$\beta_n$	Constant coefficients in Hankel functions, dimensionless
$\theta$	Angular variable in polar coordinates, deg
$\phi$	Velocity potential defined by $\bar{u} = \nabla\phi$ , ft <sup>2</sup> /sec
$\phi_A$	Velocity potential in region $A$ , ft <sup>2</sup> /sec
$\phi_B$	Velocity potential in region $B$ , ft <sup>2</sup> /sec
$\phi_I$	Incident wave velocity potential, ft <sup>2</sup> /sec
$\phi_R$	Reflected wave velocity potential, ft <sup>2</sup> /sec

- $\omega$  Angular frequency,  $2\pi/T$  , 1/sec  
 $\nabla$  Horizontal gradient operator, dimensionless

**END**

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